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ELECTRICAL ENGINEERING

MAY 1952

NORTH EASTERN DISTRICT MEETING, BINGHAMTON, N. Y., APRIL 30–MAY 2, 1952

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The Cover: West face of the Brookhaven reactor. The security walls (far left and far right) seal the area off so that it can be used by scientists for experiments without revealing classified data from other parts of the structure. See "Current Interest," page 481 of this issue.

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HIGHLIGHTS . . . .

Humanizing the Technical Speech. Certain fundamental principles should be observed when presenting a technical paper to an audience, principles which experienced speakers as well as tyros should recognize (*pages 397–400*).

Protective Relaying Over Microwave Channels. Adaptation of existing forms of power-line carrier relaying to microwave channels and several schemes applicable only to microwave channels are described. This new type of channel already has demonstrated its worth for transmission line control (*pages 400–05*).

Lightning Protection in Extra-High-Voltage Stations. The American Gas and Electric Company has undertaken a study of the design of its 330-kv stations to determine the magnitude and wave shape of lightning surge voltages. The results are expected to lead to better insulation co-ordination and selection of basic insulation level consistent with the protection needed (*pages 407–12*).

Standardizing Electrical Definitions. Chairman Dawes of the ASA Sectional Committee on Definitions of Electrical Terms considers current standardization work in two articles in this issue. In the first he discusses international agreement on definitions as exemplified by the work of the International Electrotechnical Commission (*pages 414–16*). The second article discusses the present status of the work in progress on a revision of the "American Standard Definitions of Electrical Terms" (*pages 416–18*).

Planetary Position Effect on Short Waves. For many years it was thought that sunspots were responsible for the eccentricities of short-wave radio signals, but it has been found that certain arrangements of the major planets have an added effect which must be taken into consideration when forecasting transmission conditions (*pages 421–4*).

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Application of Motors to Refrigeration Compressors. The household refrigerator of today is a long stride forward from the icebox which Tony generally forgot to fill with natural or artificial ice on hot days. The belt and shaft seals of the early electric motor-driven refrigerators were troublesome but the hermetically sealed motor and compressor have solved this problem (*pages 424–30*).

Pennsylvania Railroad Ignitron Rectifier Locomotive. Continued and intensive developments in perfecting the ignitron rectifier for broad application in the industrial and power fields revived interest recently in using it for railway work. Two Pennsylvania Railroad freight locomotives using this rectifier are described (*pages 432–7*).

High-Speed Recording Oscillograph. This instrument is capable of making permanent records of voltages having components ranging from direct current to 200 cycles per second. The waveforms are inked on a continuously moving chart with a maximum speed of 200 millimeters per second; therefore, a 200-cycle voltage wave can be traced with 1-millimeter spacing (*pages 440–5*).

Permanent Magnets From Iron Powder. Theoretical considerations show that iron powders can be made of that particle size which will produce essentially the maximum coercive force possible from the crystalline anisotropy of iron. While presently obtained coercive forces are much lower than those predicted, ultrafine iron powders offer excellent possibilities in permanent magnets (*pages 447–51*).

Safe Electric Appliance Design Principles. Because household appliances are used generally by technically uninformed persons, the design of toasters, refrigerators, vacuum cleaners, and so on must have a large factor of safety. Principles of safe design are outlined (*pages 455–9*).

Changes in Transformer Dielectric Tests. Members of the Insulation Tests Subcommittee of the AIEE Committee on Transformers have put their heads together. The results of their efforts appear on this issue as a number of proposed changes in the standard tests for transformer dielectrics (*pages 459–62*).

Mica Paper for Electrical Insulation. Mica as an insulator has been important since Edison's early motors and generators. Since then improvements have been made in the product and its manufacture. One of the more significant advances is that of continuous mica sheets (*pages 465–7*).

Servomotor Control With a Magnetic Amplifier. The application of a self-saturating magnetic amplifier to the control of a 65-watt 2-phase servomotor is described. The use of the magnetic amplifier offers several important advantages over other types of motor control for air-borne application (*pages 463–6*).

AIEE Proceedings

Order forms for current AIEE *Proceedings* have been published in *Electrical Engineering* as listed below. Each section of AIEE *Proceedings* contains the full, formal text of a technical program paper, including discussion, if any, as it will appear in the annual volume of AIEE *Transactions.*

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All technical papers issued as AIEE *Proceedings* will appear in *Electrical Engineering* in abbreviated form.

Location of Order Forms	Meetings Covered
Mar '51, p. 35A	Winter General
July '51, p. 23A	Southern District North Eastern District Great Lakes District Summer General
Nov '51, p. 37A	Pacific General Fall General
May '52, p. 37A	North Eastern District South West District

Shortage of Engineers. The role of the engineer and scientist in today's economy has become an increasingly important one, but the supply of such talent is lagging far behind demand. A solution of the problem calls for better utilization of engineering skills and the attraction of more young people to the profession (*pages 452–4*).

International Sales Through Investment. The author points out that "there are many ways in which our talents for designing, producing, selling, and taking risks can be turned to both individual profit and national and international advantages" if we refuse to let governmental restrictions deter us from investing abroad (*pages 469–72*).

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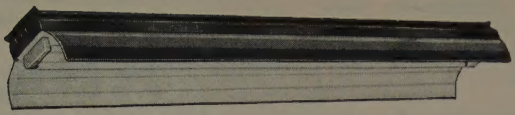

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Humanizing the Technical Speech

O. J. DRAKE GEORGE SARGENT

It is one thing to write a technical paper and quite another to present it to an audience so that the listeners not only will understand it but will remain interested in what the speaker is saying. There are certain fundamental principles involved which, if followed, will assist a speaker to hold his audience in more ways than one.

THE WORD "humanizing" in the title of this article was put there with cruel and deliberate intent. We believe that most technical speeches are not human. This is no more an indictment of engineers than it is of teachers; or of doctors, undertakers, lawyers, economists, and artists. Or of anyone else, for that matter, who attempts to speak to an audience without knowing the true nature of public speaking.

Is it worth your effort to discover this true nature? You have been to meetings and heard speeches and you know that something ought to be done about most of them. Further, you know that countless professional men and women are now pursuing courses in public speaking so that they may be better understood and more persuasive. Those men, like the great Charles F. Kettering, who can practice what is best in public speech, attest to the infinite power of the spoken word when its true nature is understood and capitalized upon.

We are not talking in this article about developing great orators; no one of us expects to become that. We are talking simply about making speeches human and we assume that this you would like to do. With this in mind, let us examine the true nature of public speaking.

THE AUDIENCE

FIRST, there is a "holy trinity" of public speaking consisting of speaker, subject, and audience—and the greatest of these is the audience. A public speech is one of the most significant of all experiences in human relations. It is an experience in which the listener is a catalyst determining precisely the extent and the nature of the communication-reaction. It is an experience in which the listener conditions definitely what and how things shall be said. It is an experience in which the speaker who is overly concerned about himself (and this is a great failing), and the speaker who is overly concerned about his subject, has misplaced his emphasis. The speaker's real concern must be with his audience. What are their desires and their interests? What is their background, experience, and knowledge on the subject under consideration? What are their limitations? How much can they take? The speaker's constant concern must be outgoing toward his listeners. In the back of his mind during preparation of his speech and occupying a little piece of his brain as he takes the platform, and a good deal of his attention while he actually delivers his message, is that little admonition, "This is for *you*, the audience." This *you* of the audience is all-important. This is the heart of "human" public speaking, the salvation for the speaker as well as for his audience. Fail to capitalize upon this concept and the speech will fall far short of your abilities.

We know that you understand this concept, and this naturally leads into a very practical second observation: A technical paper hardly can become a good public speech. Why not? Simply because the reader of a paper and the listener to a speech are not the same person. We are not human if we treat them as the same person. In a sense, an article, paper, or manuscript belongs to literature. A speech belongs to man; the listening man. It belongs to that man who is actually present; who is full of blood and nerve and muscle; a human being. He may not always act human and he may not always look human but he is human and he must be treated that way. This presence makes a great difference, and this is the real theme of our article. It is an aphorism in public speaking that, "talk as if no audience is present and soon no audience will be present."

The reader and the listener are not the same. For instance, the reader can pause when understanding becomes difficult but the listener cannot. The reader can go back as many times as necessary to get the full meaning of the words. It is most common for instructors in engineering subjects to admonish a student to "go back and read it again." This the listener cannot do.

The reader can determine his own best time and place to consider the message; the listener has no choice. The reader can see definite sight symbols such as periods, question marks, brackets, formulas, drawings, and pictures, while the listener can be shown far less of these. The reader can become relatively free from distracting influences. He can turn out bothersome lights, lock doors on other people, close or open the windows, stop his ears, settle into a comfortable (or uncomfortable) chair, smoke, take a drink, and manipulate countless other personal environmental factors but the listener cannot. Most important of all, the reader can stop when he wishes to confer with others. If he does not understand an item in his morning newspaper, he can take it to business with him and ask one of his colleagues what he believes the writer means. This the listener can never do.

The semanticist Korzybski has called the printed word

Full text of a conference paper presented at the AIEE Winter General Meeting, New York, N. Y., January 21–25, 1952.

O. J. Drake is assistant dean and **George Sargent** is assistant professor, Department of Speech, New York University, New York, N. Y.

the "great time-binder," for it transcends all measure of hours. It is an experience of timeless dimensions, but the spoken word is an experience in time. It is here today and gone, not tomorrow, but now. It is like a bird on the wing and the listener must follow it in flight, take aim, and fire, all in one instant of attention, else he is lost. This is the nature of the spoken word. Ignore this nature and the public speech breaks down. That is why the technical paper can hardly become a good public speech.

You may observe that the words of a speech easily can be set to paper and thus become, themselves, relatively timeless. True, but their nature, being aimed at man-to-man communication, is different. In the speech the speaker should not aim at telling the whole story, even if such were possible. He must be content with doing what his medium permits; give enough of the story and its details to inspire the listener to want more and thus refer to the printed word at his own convenience. If a speech were to say all possible on a subject it would be far better to distribute mimeographed copies among the audience and thus save them from the torture of listening to it. This is not to say that the spoken word is inferior to that written or printed. Each to its own good purpose. The spoken word is often far superior in capturing initial attention to a subject and often can hold that attention longer by virtue of the assets of personality possessed by the speaker. To keep it human is the task. The following paragraphs will discuss more practical applications of the two principles which have been considered thus far.

THE SPEECH

NOW THAT you see what a speech is and why it must be humanized, let us take a look at how to go about getting the speech and the audience together. Where do you start?

You should start right at the beginning when you determine what you will try to do in the speech. The point to keep in mind is this: Do not try to do too much. If you have spent three years or three months or even three weeks in learning what you know about the subject, you can hardly expect your listeners to get it all in 20 minutes. A paragraph or a sentence may suffice to recall an entire book or experiment to your mind. It will not do it for the listener who has never read the book or performed the experiment. Therefore, do not try to tell all you know about the subject. Ask yourself, "What is the important part from the listeners' point of view? The results? The method? The applications? Can I really make it clear in the time allotted to me?" Then choose the most significant part that you can cover in the time you have and really develop it.

Why is this so important? Reconsider for a moment the difference between the reader and the listener. The reader can reread, stop to think, work out a typical problem. The listener can do none of these. Yet he needs to every bit as much as the reader, perhaps more. This means that the speaker must do for the listener all those things which the reader can be expected to do for himself. You can see why, then, in a 3,000-word speech (approximately 20 minutes) you cannot cover as much material as you can in a paper of equal length. Remember, it is not when the speaker says, "I've covered the material," that the speech is a success. It is when the listener says, "I've got it."

The second point in humanizing the technical speech is to give your listeners a map. When we take an automobile trip, we like to know our destination and our route. So, too, when we listen to a speech, we like to know where we are going and how we are going to get there. Sometimes people object to doing this on the grounds that it gives the point away. But is that not just what you want to do; to give the point away, to make it clear? The technical speech is not to be treated as a murder mystery so do not be afraid to tell your listeners what you intended to do. Remember the words of the speaker who described his success this way: "First I tell them what I'm going to tell them, then I tell them, then I tell them what I've told them." Give them the map. Your purpose is to clarify, not mystify.

A third way in which you can humanize your speech is to arrange your ideas so that the listener sees his relation to your subject early in the speech. Too often the technical speech takes up construction first, then operation, then advantages and disadvantages. I suppose it is true that the equipment has to be built first, then put into operation, and that then the advantages and disadvantages show up. However when you present it, the listener, by his very nature, will not like this method. Let us see why.

When do you think about finding a good barber? Is it not when you or your wife decides that you need a haircut? When do you start looking for a tailor? Is it not when you begin to feel that your old suit is getting on in years? When, then, are you interested in listening to a technical speech? Is it not when you think that it will bring you new light, show you how to do something new or to do something old in a better way, or fill some other need? In short, is it not when you expect to get something from it that you are most interested and listen most carefully? This listener characteristic is one which you cannot afford to neglect. Early in your speech, before you start telling how something is built, show why the listeners should be interested; show them where they fit into the subject. Of course it is true that if they were not interested they would not have come in the first place, but no listener ever walked out because the speaker took pains to enlist his interest.

THE LANGUAGE OF THE SPEECH

NOW WE COME to one of the greatest of the humanizing factors, the language in which the speech is presented. Here we may find a special problem in the technical speech. We realize that complete accuracy must be maintained and, since there is no convenient synonym for $\sqrt{-1}$, some rhetorical devices available to speakers in other fields are denied to the technical speaker. We do believe, however, that this is no excuse for the technical speech to be dead. There are three principles you can follow in the use of language which will help to keep it breathing. They are: (1) Keep it simple; (2) Be yourself when you talk; and (3) Give it in small doses.

First, then, keep it simple. We do not mean to imply that you must phrase your material so that it can be understood by the man in the street, unless it is aimed at him. Terms unfamiliar to you when you began your study will be unfamiliar to your listeners until you have explained them. Therefore, do not talk in a language unknown until you are sure you have taught it to them.

Second, be yourself when you talk. Over and over we hear listeners remark, "He sounds like a book," and they do not mean it as a compliment, either. Listeners in an audience do not like to be talked at any more than they do in a classroom, office, or laboratory. Talk at a listener and he feels ignored. He feels that you do not care whether he understands or not, that you are more interested in what you are saying than you are in him. Perhaps he is right, but if you want him in his seat at the end of the talk, you had better not let him know it.

Another way to make the listener feel out of it is to use the impersonal pronoun "one." If a speaker is asked, "Who is this fellow 'one' that you always talk about?," the answer almost invariably is, "Why you and the other fellows in the audience." Now, you would not say to a friend, "If one wants some good shirts, I know where one can get them if one does not mind going downtown." Thus, why say it to him from the platform?

This is not to say that the careful and accurate use of the English language is not important. It is to say, rather, that the language should have the easy swing of conversation rather than the formalized manner of the written word. Perhaps Henry Ward Beecher went too far when he said, "When the English language gets in my way it doesn't stand a chance," but we certainly can say that the speaker who puts formalized language above his desire to communicate will not have a successful speech. So talk like yourself, not like a book.

The third principle of your use of language is this: Give your listeners your ideas in small doses. Do not give them so much at once that they can not take it in. For example:

"Since the concrete denotes thinking applied to the activities for the sake of dealing with difficulties that present themselves practically, 'begin with the concrete' signifies that we should, at the outset of any new experience in learning, make much of what is already familiar, and if possible connect the new topics and principles with the pursuit of an end in some active occupation. . . ."

Now, if we had to depend for our lives upon our understanding of this paragraph in one reading, there probably would not be many of us around next week. The idea is simple enough, however. It simply says that "begin with the concrete" means to begin by showing the new principle in a familiar situation. All of us find the temptation great to display our own erudition through esoteric means of expression that tend to obfuscate the point we are trying to clear up! But it does not help to clarify, so lessen the individual dose, keep it simple, make it conversational.

VISUAL AIDS

So far we have been considering the speech the listener hears. How about the one he sees? The speech he sees may be just as important as the one he hears. What does he see? First, he sees the speaker. He also sees visual material which you display to make it easier for him to understand. Here are some suggestions about visual aids.

First, do not display anything until you are ready to use it. Most people are more eye-minded than ear-minded and if you show your drawings, pictures, diagrams, and so forth, before you are ready to use them, your listeners will spend their time trying to figure them out and will not be listening to you.

Second, make them big. Visual material is no good if it cannot be seen by everybody in the room. I know of no case where a speech failed because the visual aids were too large. I have seen many fail because they were too small.

Third, make them as simple as possible. If you use a circuit diagram, for example, do not show parts you will not cover. A good number of people will always look at the wrong thing. Do not cover the drawing with labels that you will explain anyway. Diagrams in your written papers have to be labeled because you will not be there to explain them to the reader. As a speaker you can dispense with many of them and those you do use should be simple.

Fourth, when you have finished with them get them out of sight. You want attention on what you are saying, not on the visual part of what you have already said.

Fifth, do not hand out samples to be passed around. By the time they get to the back of the room, you will long since have been talking about something else. Use a model or a drawing that everybody can see at the same time and when you have discussed it, get rid of it. In this way, your visual material becomes an aid rather than a hindrance.

These, then, are five factors in humanizing your technical speeches. Follow them and your technical speeches will become human, something more than a technical paper "on its hind legs."

Thus far we have discussed the listener and his relation to you and to your subject. In the following paragraphs we will consider the third factor in our trinity, you, the speaker.

THE SPEAKER

What can be said about the speaker himself that will help to "humanize" the speech? First, do not worry about posture, gesture, vocal inflection, and the like until you know that you are actually abnormal in one of these respects. The chances are that you are perfectly normal and will be effective enough if you can learn to do two big things:

1. Have a complete mastery of your subject. Do not memorize it but be so conversant with every phase of that portion which you intend to cover in your talk that you can answer all questions concerning it.
2. Have an overpowering desire to let your audience in on your thoughts and your feelings.

If you have mastered your subject and if you have become genuinely interested in your listeners, we believe that approximately 80 per cent of your problems in delivery have been solved. Some problems may remain, for public speaking is a learned process in part, perfected through the recognition of certain principles and their consistent application. The cardinal rule is that the speaker must employ all the resources of his personality during the delivery of his speech. He uses these for the one great purpose of gaining and holding attention. This is his responsibility alone. No audience ever breathed that did not want to know more, but it is your responsibility as a speaker to bring it to them. It is a responsibility, but it is also a great opportunity, for here they sit, eager to learn, and there you are, eager to give a bit of knowledge upon which you have earned the right to talk to them.

Here are just two specific suggestions:

1. Look at your audience all of the time. Remember that this is an experience in human relations and that keeping your intelligent attention upon the listener helps to establish the 2-way relationship necessary to genuine communication.
2. Use variety in everything you do. Nothing commands attention as much as does change. This applies to the use of your body as well as to the use of your voice.

We believe that the spoken word demands that the audience play a more important part than generally is assigned to it and that you will be human in your speaking only if you recognize and practice that principle. We believe that the same message composed for a reader will not suffice for the listener. We believe that there are a few fundamental principles which, if applied diligently, will increase the power of the spoken word tenfold in any instance. And we believe that thus will your speeches become human.

Protective Relaying Systems Using Microwave Channels

H. W. LENSNER
MEMBER AIEE

As a new means for expanding and improving power system operation, microwave channels offer some important advantages over older systems for protective relaying. Several methods for using microwave channels for this purpose are described in this article.

THE RAPID GROWTH of power systems both in capacity and extent has increased the need for high-speed clearing of faults to improve system stability and continuity of service. Pilot channel relaying has been used for many years for high-speed simultaneous circuit breaker operation and the advantages of such forms of relaying are well known. Both pilot-wire and power-line carrier channels are widely used to transmit the necessary information between stations. Pilot wire relaying is particularly suited to large metropolitan areas where line sections are relatively short and leased or private cable circuits are available. For longer power circuits and interconnections, carrier has an economic advantage as well as providing for additional functions. In many sections of the United States, however, the available carrier channels are rapidly being exhausted because of expansion and the trend toward centralized system control.

In the last few years, microwave channels have become available as a new means for further expanding and improving the operation of a power system.[1] This new type of channel has several advantages. It is independent of the power line so no line traps or high-voltage coupling capacitors are needed. Furthermore, it is not necessary to take a line section out of service to check or maintain any component of the microwave equipment. Being dissociated from the power line, performance of the channel is unaffected by the line noise or switching disturbances. Extensive tests in the 960-megacycle band[2] have demonstrated that operation is essentially independent of weather.

It is the purpose of this article to present several methods of utilizing microwave channels for protective relaying. Adaptations of existing forms of power-line carrier relaying and several schemes applicable only to microwave channels will be discussed, as well as some operational problems related to microwave channel performance.

ADAPTATIONS OF EXISTING SYSTEMS

THE FIRST THOUGHT in using a microwave channel for protective relaying is to adapt present forms of power-line carrier relaying for use over a microwave channel. For such service, an audio tone is used as the "carrier" rather than the microwave frequency itself which is capable of providing many voice channels simultaneously. The term "audio tone" as used here is not restricted to a fre-

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Full text of paper 52-51, "Protective Relaying Over Microwave Channels," recommended by the AIEE Committees on Carrier Current and Relays and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 21–25, 1952. Scheduled for publication in AIEE *Transactions*, volume 71, 1952.

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quency audible to the human ear, but may be any frequency within the modulation capability of the microwave equipment. Audio tones in a nominal voice channel of 250 to 3,150 cycles per second can modulate the microwave frequency directly, or may be impressed on one of the multiplexed voice channels.[3] If the full complement of voice channels is not used, higher frequency tones (up to 30 kc for a 960-megacycle microwave signal) also can modulate directly the microwave frequency. Such direct modulation has the advantage of bypassing the multiplexing units in both the transmitter and receiver. This results in considerable simplification since fewer tubes and circuits are involved with direct modulation.

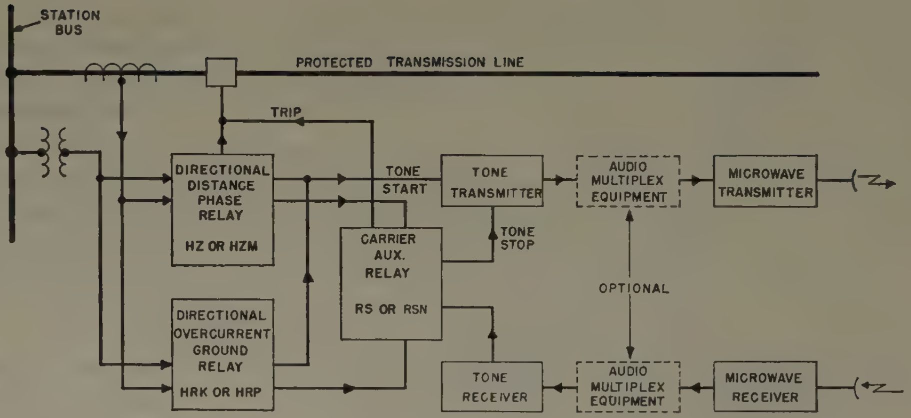

Figure 1. Block diagram of the elements of one terminal of directional-distance tone relaying over a microwave channel

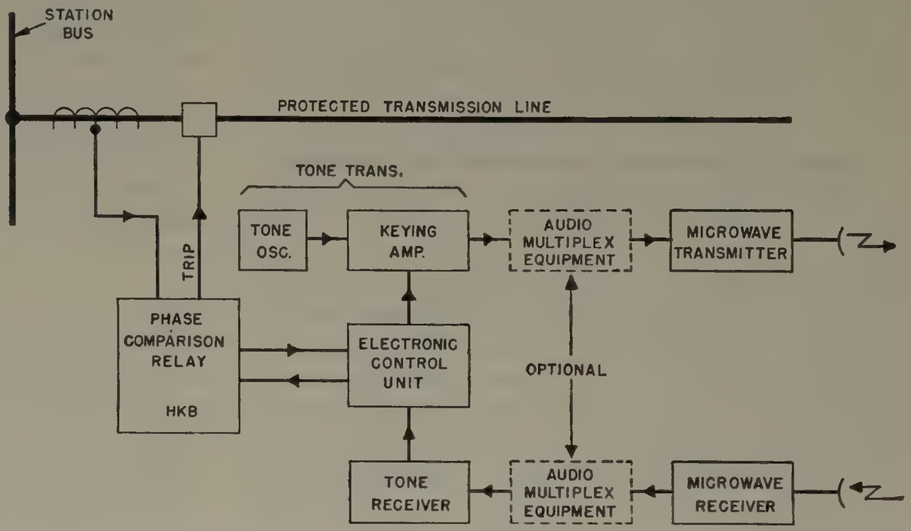

Figure 2. Block diagram of the elements of one terminal of phase-comparison tone relaying over a microwave channel

Both the directional-comparison-distance type[4,5] and the phase-comparison type[6] of relaying can be adapted readily to use a tone "carrier" signal. The units required for the directional-comparison system are shown in block diagram form in Figure 1. As in conventional carrier relaying, the phase and ground relays control the transmission of the blocking signal through the carrier auxiliary relay. Because the time constants of circuits at the tone frequencies are longer than at carrier frequencies, some delay may be necessary in setting up the carrier trip circuit to allow for the build-up time of the restraint current derived from the received tone. This delay is in the order of only 0.5 to 0.7 cycle (on a 60-cycle basis) when using standard voice-frequency tones, and may be dispensed with entirely when wide-band high-frequency tones (above the normal voice band) are used. Because of the wider passband of the filter, the build-up time of these tones is less.

Since the tone blocking channel is not used for any other function as it may be with power-line carrier, the tone can be transmitted continuously, thus providing a means of supervising the channel. Even with continuous tone transmission, the tone build-up time must be considered because of the relay operation during a power reversal which takes place when nonsimultaneous circuit breaker operation occurs. When the first circuit breaker opens, there may be a reversal in the direction of power flow in an unfaulted parallel line. This is accompanied by a reversal in the direction of transmission of the blocking signal, at which time the delay in build-up of the restraint current must be taken into consideration for correct relay operation.

The elements of a phase-comparison tone relaying system for microwave channel use are shown in Figure 2. A single-phase output voltage from the phase comparison relay energizes the electronic control unit. This unit, in turn, controls the transmission of half-cycle (at 60 cycles) blocks of tone energy. The tone transmitter is made up of two parts: an oscillator which operates continuously, and a keying amplifier which controls the tone transmission. This arrangement is used to avoid the delay in build-up time which would result if an attempt were made to key the oscillator directly as is done at carrier frequencies where the circuit time constants are short enough to permit direct oscillator keying. As previously explained, the relaying tone may modulate the microwave signal either directly or through audio multiplexing equipment as shown. The received tone pulses are separated from the remainder of the microwave receiver output using a wide-band filter to minimize delay, and are compared with the phase position of the local relay output in the electronic control unit.

Again, because of the longer time constants of the tone filters and associated circuits, the received pulses of tone-restraining voltage lag approximately 2.5 milliseconds

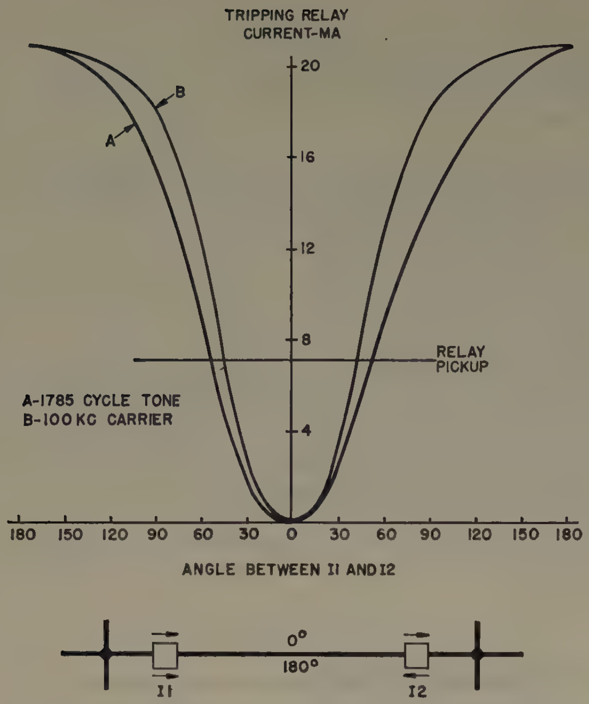

Figure 3. Operating characteristics of phase-comparison relaying system over carrier and tone channels

(55 degrees on a 60-cycle basis) behind the transmitted signal. To compensate for this delay, the local operating voltage is shifted a like amount for proper operation of the "comparing" circuits. Without such compensation the relay either might trip on external faults or block on internal faults. There is no particular advantage, from a relaying standpoint, of continuous transmission of the tone-blocking signal with phase comparison relaying since the tone must be started and stopped 60 times a second during a fault. However, if continuous supervision is desired, the tone can be transmitted continuously except during the time of a fault.

The operating characteristics of phase-comparison relaying systems using a 100-kc carrier and a 1,785-cycle tone are plotted in Figure 3. By proper choice of circuit constants, these two characteristic curves are brought reasonably close together. The blocking angle for either type of channel is approximately the same, and the variation above the tripping relay pickup current is of no consequence.

FIELD EXPERIENCE ON MICROWAVE RELAYING

A FIELD INSTALLATION of microwave relaying using both directional-comparison-distance type and phase-comparison relaying operating in the 960-megacycle band was made on the system of the Pennsylvania Electric Company. The reliability of the microwave channel was amply proved over a $2^1/_2$-year period of operation. During this time, the reception of the microwave signal was not adversely affected by variations in temperature or other weather conditions. In addition to the relaying, other functions on the channel included three voice circuits, two telemetered quantities, and supervisory control of eight points.

Staged fault tests were made which included both tripping and blocking operations of the two types of relaying. Internal faults were separately put on each of two parallel lines protected by one of the relaying systems. This provided both tripping and blocking operations for each set of relays. A third fault which was put on the line section beyond the relays was external to both protected lines.

Because this installation was experimental in nature, no emergency power supply was provided to maintain the microwave channel in the event of failure of the normal 120-volt 60-cycle supply at either station. During one of the staged faults, the alternating voltage at one microwave terminal dropped enough to interrupt momentarily the blocking signal. As a result, the relay at the opposite terminal tripped on an external fault. This operation emphasizes one of the prime requisites of a microwave relaying installation—a 100-per-cent-reliable power source. In the event of failure of the normal supply, some emergency source of power immediately must be connected to the microwave equipment to prevent even a momentary interruption of the channel. With this exception, the relay operation was correct on the staged tests.

REMOTE TRIPPING

REMOTE TRIPPING is another relaying function which is adapted readily to a microwave channel. Two audio tones can be used, and the transmission of both tones simultaneously is required for tripping the remote circuit breaker. A variation of this scheme which has come into some use consists of transmitting one tone continuously as

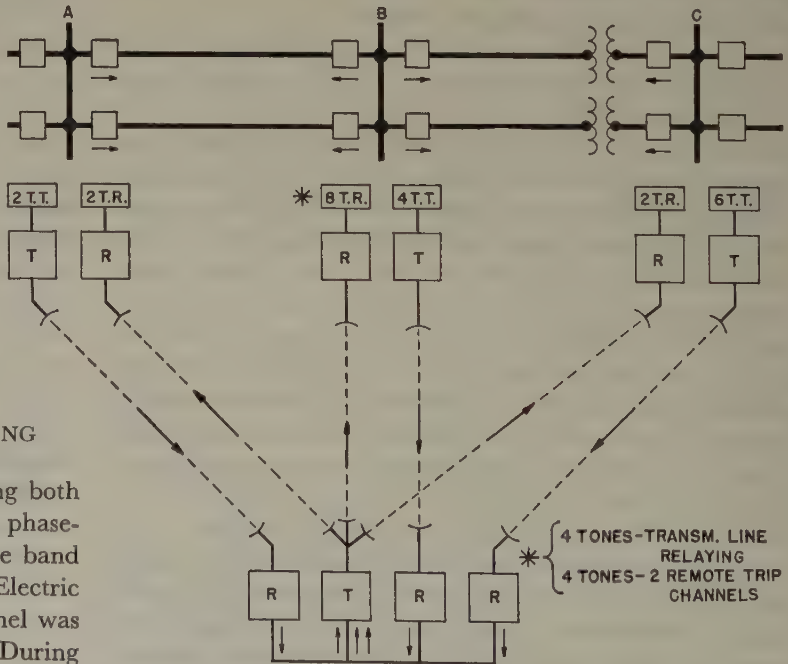
A
B
C
2 T.T.
2 T.R.
*
8 T.R.
4 T.T.
2 T.R.
6 T.T.
T
R
R
T
R
T
R
T
R
R
*
4 TONES-TRANSM. LINE RELAYING
4 TONES- 2 REMOTE TRIP CHANNELS

Figure 4. Microwave relaying and remote tripping using a central dispatching point as a repeat station when direct line-of-sight paths are not available

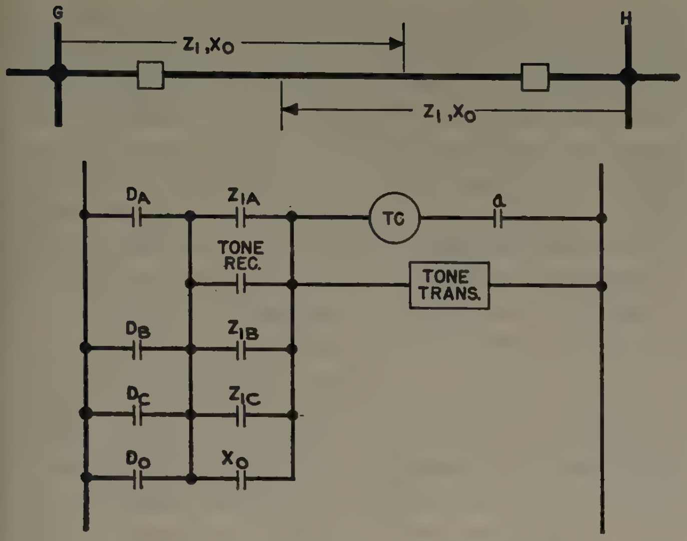

Figure 5. Transferred-trip scheme using directional-distance relays for phase and ground fault protection

a blocking signal (sometimes called guard tone), then stopping this tone and transmitting the second tone for tripping. Either of these schemes has the advantage that the tones can be tested one at a time without removing the equipment from service.

Operating a remote tripping scheme using audio tones over a microwave channel as described has several advantages over a power-line carrier application. First, the entire equipment is dissociated from the power line, and the channel is thus unaffected by changes in system conditions. Second, the arcing caused by operation of disconnect switches presents no interference problem at the microwave frequencies. Also, the microwave equipment is unaffected by transient disturbances on the station battery which may affect carrier operation unless suitable precautions, such as added filtering, are taken.

An example of the application possibilities[7] of microwave relaying is illustrated in Figure 4. In this example, the microwave installation may have been made previously as a central dispatching point to stations *A*, *B*, and *C*. These microwave channels also might be used for telemetering, load control, and supervisory control. If the installation were made primarily for relaying, the location of the microwave repeat station may have been dictated by lack of line-of-sight paths between the stations. As shown, the two parallel lines between stations *A* and *B* are relayed through the repeat point using separate audio tones in each direction on each line. The two lines between stations *B* and *C* are similarly relayed, but include transformer banks which must be relayed by remote tripping since there are no high-voltage circuit breakers at station *C*. Consequently, at station *C*, two tone transmitters are used for relaying of the two lines to station *B*, and four more tone transmitters are used for two remote-trip channels (using two tones on each channel) for a total of six tone transmitters. Only two tone receivers are needed at station *C* for relaying of the lines to station *B*.

At station *B*, four tone transmitters and tone receivers are required for line relaying, and four additional tone receivers receive the remote tripping signals from station *C* for transformer faults.

RELAYING SCHEMES FOR MICROWAVES ONLY

When considering a microwave channel for protective relaying, there is one important difference in comparison with power-line carrier. With microwaves, the channel is completely dissociated from the power line. Thus it becomes possible to send a tripping signal over the channel during an internal fault. Such an operation never has been considered dependable with power-line carrier, because the fault itself may short-circuit the carrier signal to ground and prevent its reaching the remote terminal. This condition obviously cannot exist with a microwave channel.

One possible scheme for microwave transferred-trip relaying is shown in Figure 5. At each station, a single-zone impedance element (per phase) in conjunction with a directional element, is set to reach more than halfway toward, but not beyond, the opposite station bus. In addition to completing the trip circuit of the local circuit breaker, directional and impedance relays start the transmission of a tone to the opposite line terminal where the tone receiver relay contact bridges the impedance element contact. For a fault in the zone where the impedance settings overlap, simultaneous high-speed operation of both circuit breakers takes place, independently of the microwave channel. For a fault in either end zone, the near relay operates to complete the trip circuit and start a tone. Reception of that tone at the other terminal completes its trip circuit and thus provides high-speed sequential operation where the only delay is the operating time of the tone receiver, but not the first circuit breaker time. Allowing 1 cycle operating time for the protective relay and 1 cycle for the tone equipment, the total operating time for this relaying scheme is in the order of 2 cycles. Three single-zone directional-distance or impedance relays for phase fault protection plus a directional-reactance relay for ground faults comprise the relay requirements for this scheme, as shown in Figure 5.

Another type of microwave transferred tripping is shown

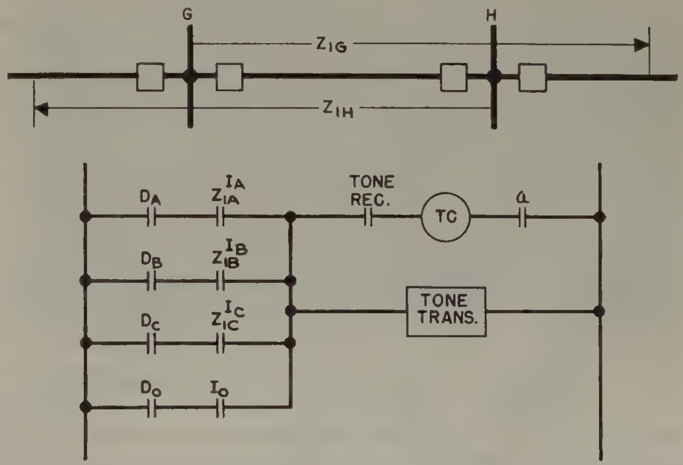

Figure 6. Transferred-trip scheme which can use either directional-distance or directional-overcurrent relays for phase and ground fault protection

schematically in Figure 6. In this system, directional-impedance or directional-overcurrent relays can be used. The main requirement is that the relays "reach" through the protected line section and a reasonable distance beyond, to insure that they will operate positively for a fault anywhere in the section. As in the previously described scheme, operation of the relays starts the transmission of a tone to the opposite terminal. The trip circuit is completed only when the tone is received over the channel and the local directional and impedance or overcurrent relays also operate. In Figure 6, for a fault in the line-section *GH*, at both stations relay contacts *D* and *Z* or *I* will close to energize the tone transmitter. Transmission of the tone from each terminal to the opposite terminal will close the tone receiver contact to complete the trip circuits at both stations. The operating time of this relaying system is also approximately 2 cycles.

For an external fault just to the right of station *H* in Figure 6, the directional and impedance contacts at station *G* will close to start tone transmission to *H*. However, at station *H*, the directional contacts will remain open since power is flowing out of the line at that terminal. Under this condition, there will be no transmission of a tone from station *H*. Consequently, the trip circuits at both stations *G* and *H* will remain open for this external fault. In the scheme of Figure 6, it is essential that the tone receiver relay contact open before the directional element contact closes during a power reversal as previously discussed. If it does not, proper co-ordination can be obtained by the addition of an auxiliary relay in the trip circuit that adds only a few tenths of a cycle to the over-all tripping time.

The choice between the schemes of Figures 5 and 6 is largely a matter of personal preference. The scheme of Figure 5 will give some protection even when the microwave channel is out of service. In this respect, its performance is essentially the same as first zone operation of distance-type carrier relaying when the carrier is switched off. The scheme of Figure 6 requires the tone over the microwave channel for any tripping operation. Without the tone, there can be no tripping through the associated high-speed relays. However, the relay requirements are less exacting in the scheme of Figure 6. Simple directional-overcurrent relays can be used (where load conditions permit) for phase and ground fault protection, whereas distance-directional relays are required in the scheme of Figure 5 for both phase and ground relaying. It should be pointed out that the relaying schemes of Figures 5 and 6 are shown in elementary form. Other considerations such as backup relays and out-of-step protection are a separate problem and need not be discussed here.

POWER SUPPLY CONSIDERATIONS

Microwave transmitters and receivers require higher tube plate voltage for satisfactory operation than is available from a station battery. For this reason, rectifier power supplies are used to supply the required direct voltage which is in the order of 300 to 500 volts, and in addition supply low alternating voltages for tube heater circuits. Such power supplies are usually energized from the 120-volt 60-cycle circuits which are available in the power station.

When a microwave channel is to be used for protective relaying, it is essential that there be no interruption of power which could allow incorrect operation of the relays. Such a requirement precludes the use of the local a-c source unless some provision is made to assure continuity of service even during fault conditions when such a source may be interrupted. One possible answer to this problem for power station use is a 3-unit motor-generator set consisting of an a-c motor, a d-c motor, and an a-c generator all on the same shaft. The assembly is normally driven from the a-c motor, and the microwave equipment is energized from the a-c generator. Since the total power required for a microwave assembly is generally less than 1,000 watts, the motor and generator losses are negligible from an economic standpoint. In the event of failure of the normal a-c supply, a high-speed undervoltage relay switches the drive from the a-c motor to the d-c motor which is energized from the station battery. The inertia of the rotating assembly is sufficient to maintain the voltage through the switching time, thus allowing continuous transmission and reception of the microwave carrier and associated tones for relaying. When the alternating voltage returns to normal, the a-c motor again drives the assembly to minimize the drain on the station battery.

This emergency power supply system will be satisfactory for most relaying installations where the microwave equipment is located at the line terminals, and station batteries are available to drive the d-c motor. However, in relaying a line that is too long for a single microwave channel, or where there is intervening terrain, a repeat

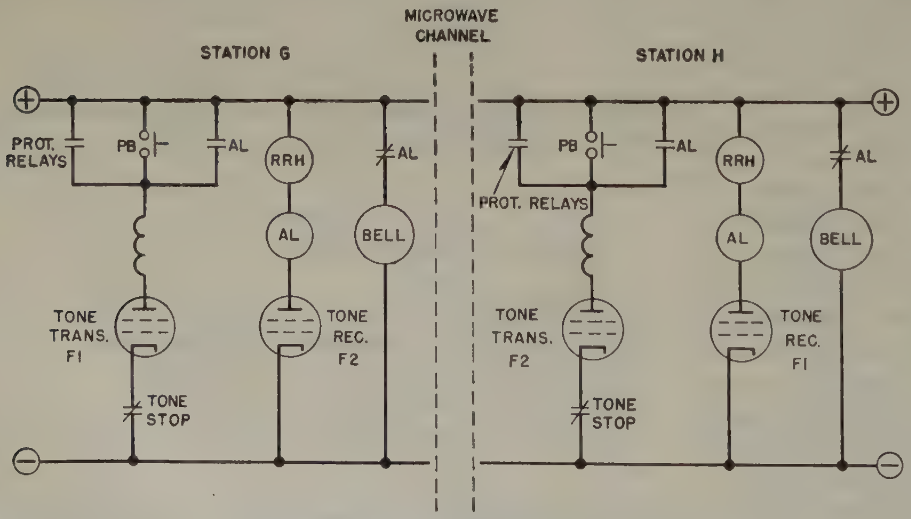

Figure 7. Scheme for providing continuous supervision of a tone blocking channel for distance relaying

station may be located at a remote point where the only source of power is the local a-c line. No general solution can be given for this problem. There are several possibilities, however. A large capacitor bank across the plate-voltage supply would carry the load through momentary dips in voltage. For longer interruptions, a heavy-duty vibrator supply energized from a low-voltage storage battery could provide the plate voltage, while the tube heaters would be energized directly from the battery. For extended power outages where continuity of service is important, a diesel- or gasoline-engine-driven generator then could be used to supply a-c power to the entire microwave repeat station. Any of these schemes or a combination of them might be employed to insure against interruption of the microwave channel caused by failure of the primary power source.

SUPERVISION OF CHANNEL

As WITH POWER-LINE carrier, some means of manually or automatically checking the channel periodically is desirable. Since the microwave signal is transmitted continuously, a meter connected in an appropriate part of the receiver circuit can be used to indicate reception of the signal. This would not check the associated tone components used for relaying, however. These could be checked manually by push button noting the receiver plate current or the operations of a lamp or bell in the tone receiver alarm element circuit. Similarly, automatic check-back timing relays could be used to check the channel[8] at periodic intervals, such as every hour. For the scheme of Figure 5, it would be necessary to use two tones electrically interlocked, or remove the relaying from service when checking the single tone shown. Otherwise, tripping would result at the terminal where the directional contacts (*D*) were held closed by the load power flowing into the line.

An arrangement for continuous supervision of a tone-relaying channel for distance relaying is shown schematically in Figure 7. The particular feature of this scheme is that failure of the blocking channel in either direction gives an alarm at both stations. In the diagram, *RRH* is the holding coil of the receiver relay and *AL* is the alarm relay.

Operation of the scheme is as follows: The push button *PB* at station *G* is manually closed momentarily to start transmission of the blocking tone *F*1. This tone is received at station *H* by the tone receiver, and energizes the alarm relay *AL*. One contact on the alarm relay closes to start the transmission of tone *F*2 back to station *G*. Another contact opens the bell circuit. Reception of tone *F*2 at *G* energizes the alarm relay at that station. One contact seals in around the push button which started the sequence, and another contact opens the station *G* bell circuit. The channel supervision is now in operation. Failure of any element of the 2-way channel will cause both alarm elements to drop out and sound the alarm bell at both stations. The protective relays still have preference in controlling the transmission of the tone signal. Upon the occurrence of an internal fault, the tones are stopped by operation of relays in the tone transmitter cathode circuits (as shown in Figure 7) regardless of how they were started.

CONCLUSIONS

1. Microwave channels can be used to advantage to supplement power-line carrier for transmission line relaying.

2. The practicability and reliability of microwave channels for relaying has been confirmed by laboratory and field tests.

3. Microwaves can provide many new channels in locations where the carrier spectrum has been fully utilized.

4. Because of its separation from the power line, microwave channels offer the possibility of new relaying schemes not feasible on power-line carrier.

5. Microwaves present a new field for future development of the relaying art.

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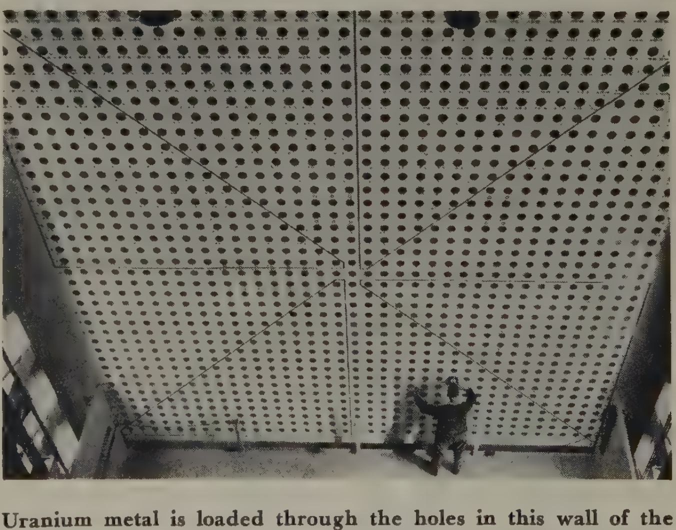
South Face of the Brookhaven Reactor



Uranium metal is loaded through the holes in this wall of the Brookhaven reactor (see complete story on page 481) into the graphite moderator and uranium atoms fission in a chain reaction. The technician, shown standing on an elevator which enables him to move to any level of charging holes, is using a periscope to view the handling of radioactive sources by remote control. A concrete wall, 5 feet thick, protects him from radiation

A Ratio Instrument for Resistance Thermometers

E. W. CLARK
MEMBER AIEE

RESISTANCE thermometers have several advantages over other types of temperature-measuring equipment especially in the −150- to +150-degree centigrade range. They are inherently stable and accurate, and the end device may be located several hundred feet from the primary detector without affecting calibration. There are no cold-junction errors requiring compensation, such as are encountered in thermocouple thermometers. Although resistance thermometers have been used for many years in standardizing work in thermometry and for aircraft temperature measurements, they have not been used extensively in industrial applications. The primary reason for this is that instruments which combine high sensitivity and simplicity with sturdy construction have not been available to make practical an industrial resistance thermometer which consists essentially of a resistance temperature detector, a power supply, and a ratio instrument.

To fill the need for such an instrument, the high-sensitivity ratio instrument described in this article was developed. Tentative specifications called for a scale span of 50 degrees centigrade when used with a 10-ohm copper-resistance temperature detector; accuracy of ±0.5 per cent of full scale; sturdy construction; a 7-inch scale with reasonably linear distribution; means for control initiation; and relative freedom from external influences.

Conventional off-center-core and crossed-coil eccentric-core ratio mechanisms proved to be inherently unstable at the high sensitivities required. This led to the development of the new crossed-coil cut-pole-face ratio mechanism shown in Figure 1.

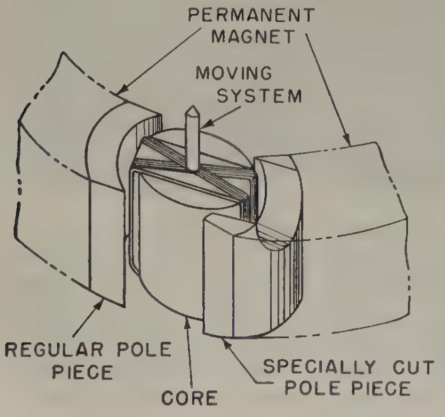


Figure 1. New cut-pole-face ratio mechanism

The moving system is similar to that used in the crossed-coil eccentric-core ratio mechanism, but the desired relationship between the value of flux seen by the coils and angular deflection is obtained in a novel way. In this mechanism, the core is concentric with the pole faces providing a uniform gap, but one pole face is cut in such a way as to reduce the effective height of the pole. Neglecting the effect of leakage flux distribution, the average value of flux seen by the coil varies with the effective height of the pole at the center line of the coil. The ratio action in this mechanism is accomplished by a variation in the height of the pole face which is about 1¼ inches while in conventional ratio mechanisms ratio action is accomplished by variations in the air gap which is about 0.050 inch. An accepted criterion for comparing electric instruments is the torque-to-weight ratio and for vertical pivot instruments the ratio of torque to the 1½ power of the weight. For this instrument: $T/W=1.02$, $T/W^{1.5}=0.73$.

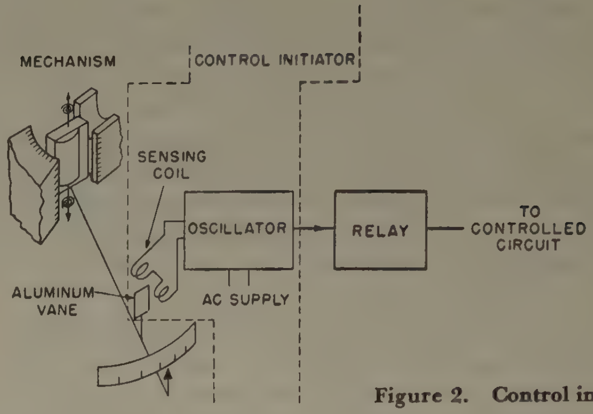


Figure 2. Control initiator

Control initiation is provided by a small aluminum vane mounted on the pointer arm. See Figure 2. The vane may enter the space between two sensing coils (adjustable for scale position) and thereby reduce their effective inductance. When this occurs an electronic oscillator circuit to which the coils are connected starts oscillating, thereby reducing the oscillator plate current sufficiently to open a relay in its circuit. When the vane is removed from the space between the coils the reverse is true and the relay closes.

The new crossed-coil cut-pole-face ratio mechanism makes practical the extensive use of resistance thermometers for industrial temperature measurement and control. The new cut-pole-face construction combined with a crossed-coil moving element, a very high strength Alnico V magnet, and low-torque spirals result in a resistance thermometer having the following characteristics: 1. high sensitivity (scale spans as small as 50 degrees centigrade); 2. high accuracy (±0.5 per cent of full scale); 3. sturdy construction; 4. legibility (7-inch linear scale); 5. simplicity (manufacturing and maintenance problems less critical than in prior instruments); and 6. versatility (may be changed from indicator to controller by adding electronic relay).

Digest of paper 52-55, "A High-Sensitivity Ratio Instrument for Industrial Resistance Thermometers," recommended by the AIEE Committee on Instruments and Measurements and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 21–25, 1952. Scheduled for publication in AIEE *Transactions*, volume 71, 1952.

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A Study of Lightning Protection in Extra-High-Voltage Stations

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Results of this study reveal that variations in magnitude and wave shape of voltages caused by lightning surges in extra-high-voltage stations are great enough to be of economic importance in the selection of insulation levels of station equipment.

IN RECENT YEARS it has been general practice to limit the magnitude of lightning and switching surge voltages in stations by the judicious application of lightning arresters or air gaps, or both. Current practice in many companies is to locate the lightning arrester directly on the large and expensive power transformers, thus reducing the likelihood of damage to that part of the station where a failure would be most detrimental to power equipment and electrical service. Not too much thought usually has been given to protection of other parts of the station such as bus insulators, instrument transformers, circuit breakers, coupling capacitors, and other such equipment remote from the lightning arrester.

It is known, however, both by theory and field and laboratory test results, that the voltage reduction produced by the lightning arrester is greatest at the lightning arrester terminals and is not present to the same degree at various other points in the station. In a small station, physically limited in extent, the variations in voltage magnitude and wave shape may not be of significant importance, but where high-voltage, and particularly extra-high-voltage, stations are involved these variations do become significant.

Because of this situation, a study was undertaken in the station design of the American Gas and Electric Company 330-kv stations. Not only was it expected that better insulation co-ordination thus would be obtained, but also considerable economic benefit would result from the selection of basic impulse insulation levels for various pieces of equipment consistent with the protection needed.

LIGHTNING VOLTAGE CHARACTERISTICS IN STATIONS

A LIGHTNING SURGE may enter a station either by direct stroke or traveling wave over the incoming transmission lines. It is assumed in this study that the station is adequately shielded from direct strokes so that only traveling waves from the lines can enter the station. It is also assumed that the line for a distance of a mile or more from the station also will be so well shielded, and have such low tower footing resistances, that neither direct strokes nor back-flashes (from tower to line conductor) in this location will occur.

Traveling waves of various shapes, depending on their method of origin, and having magnitudes determined by the line insulation near the station entrance, may enter the station. When the wave enters the station, regardless of its wave shape, it will be changed in form by the capacitance, inductance, terminal equipment, and branch circuits within the station. In a station consisting of one transformer bank and one outgoing line, the maximum destructive effect of waveform change at points remote from the arrester can be expected. As power supply circuits are added and as the outgoing circuits increase, these in general tend to reduce the severity of the voltage wave at other parts of the station remote from the arrester. For this reason the simple one-source supply and one outgoing-circuit type of station was selected for basic analysis.

The case where the incoming voltage wave encounters an open circuit breaker which prevents it from entering the station was not considered. System operation with the circuit breakers open and hence with the transmission line out of service is deemed sufficiently rare to permit ignoring it. Furthermore, since the transmission line is then out of service, flashover to ground on the line side of the open circuit breaker will not affect system service.

In general, lightning waves entering a station are altered in magnitude. But the natural characteristics of the station circuit which tend to reduce the crest magnitude slightly also will reduce the magnitude of the wave tail considerably. This becomes significant as the station becomes more extensive with numerous tap connections and capacitances which are inherent in any modern generating, transmission, or switching station. It appeared possible that these characteristics, in combination with the volt-time characteristic of the insulation, would permit the use of lower basic impulse insulation levels for some equipment than would be required if the full destructive effect of an incoming wave were applied directly and without alteration to equipment located some distance from the lightning arrester. This feature has considerable economic possibilities in reducing the basic impulse insulation level of circuit breakers which in the past have rarely, if ever, been given direct lightning protection by placing the lightning arrester at the circuit-breaker terminals. It was in connection with the selection of circuit-

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Essential text of paper **52-107**, "Lightning Protection in Extra-High-Voltage Stations—Analysis, Anacom Study, and Results," recommended by the AIEE Committee on Transmission and Distribution and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 21–25, 1952. Scheduled for publication in AIEE *Transactions*, volume 71, 1952.

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Table I. Waves Assumed to Approach Switching Station Over Phase Conductor

Wave Number	Type	Caused by*	Crest Voltage, kv	Rate-of-Rise of Front, kv/microsecond	Time to Half-Value, microsecond
1	Chopped	*a*	2,000	500	Chopped at 4 microseconds
2	Short-tail	*b*	1,600	500	10
3	Full	*c*	1,600	500	40
4	Chopped	*a*	2,000	1,000	Chopped a 2 microsecond
5	Short-tail	*b*	1,600	1,000	10
6	Full	*c*	1,600	1,000	40

* *a*—Stroke to conductor and insulator flashover. *b*—Stroke to grounding system and insulator flashover. *c*—Stroke to conductor and no insulator flashover.

breaker basic impulse insulation levels that this problem became decidedly important.

SYSTEM LAYOUT

The type of station for which this analysis was particularly made was the 330-kv system mentioned. A cross section of a typical 330-kv station is shown in Figure 1 where approximate distances between various points in the station and also circuit feet are partially shown.

The reason why such greater distances are required, rather than those used in the lower voltage circuits now commonly in use, is apparent when the physical layout is considered. The 200,000-kw generator will feed directly into a transformer located near the station building. Transmission at 330 kv will be some 2,000 feet or more to a location where a station structure can be located adequate to take not only the first circuit but additional circuits later.

The station itself will use equipment such as circuit breakers, disconnecting switches, and the like, which are themselves physically large. Clearance must be adequate not only to withstand all expected overvoltages, but also to provide sufficient space for maintenance with various parts of the station "hot" and also for hot-line maintenance which is now contemplated.

A conversion of the one-line diagram and station cross-section layout into equivalent one-line diagrams, dimensioned for use in the study, is shown in Figure 2. Variations in distances between the three cases shown result from assuming different circuit breakers and switches being open or closed. Each case presents a single straight circuit from the incoming line at the station entrance through to the transformer with various tap connections to by-pass switches, busses, and duplicate equipment which hang on the bus during normal operation. Thus there is a single-wire transmission line with taps from which reflections come back which affect the characteristics of a lightning voltage wave coming in over the line.

TYPES OF WAVES

In order to evaluate the degree of protection obtained, attention must be given to defining the magnitudes and shapes of the incoming surges to be considered. All of the wave shapes considered in this study fall in three general categories according to their time to half-value.

Short-Tail Waves. One category is that resulting from strokes to the line shielding system of sufficient magnitude to flashover one or more insulator strings and so bring the phase conductor up to the tower top potential. The characteristics of the surges in this category were arrived at through use of the following constants:

1. Tower footing resistance, 10 ohms.
2. Tower inductance, 20 microhenrys.
3. Coupling factor between ground wire and phase conductor, 25 per cent.
4. Shape of stroke current wave, 4x40 microseconds.
5. Number of insulators per string, 18—$5^3/_4$-inch units.

The coupling factor was calculated on the basis of estimated line configuration distances, and the number of insulators is that to be used on the projected high-voltage transmission line. On the basis of standard test waves, it is found that stroke currents of at least 180,000 amperes are required to cause a backflash. For the 180,000-ampere stroke, the rate of change of current in the tower is $180/4 = 45$ kiloamperes per microsecond, and the Ldi/dt drop is $20 \times 45 = 900$ kv. The resistance drop is $180 \times 10 = 1{,}800$ kv, and the potential across the insulator

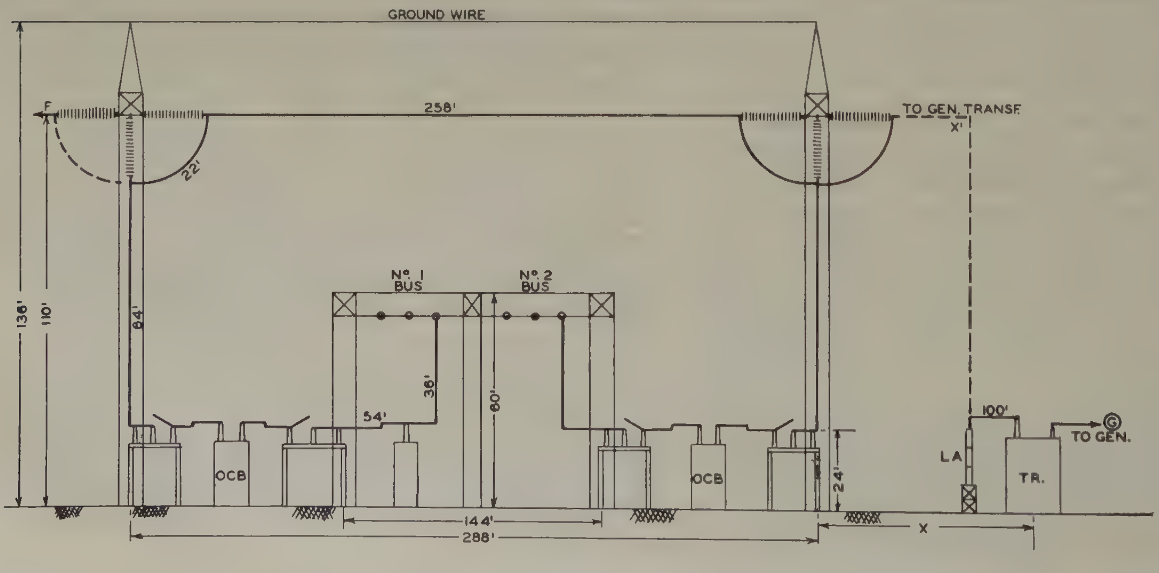

Figure 1. Elevation through switchyard showing relative location of equipment and certain circuit distances

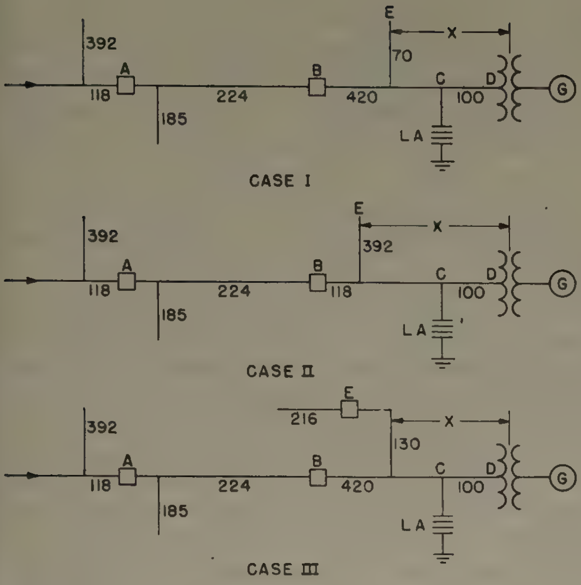

Figure 2. Diagrams for three different connections within the switching station with lengths of circuits denoted in feet

string is $(1-0.25)\times(900+1,800)=2,025$ kv, about the 3-microsecond flashover value for 18 insulators with the standard test wave.

An analysis made of the voltage on the phase conductor resulting from a backflash, using the constants given, indicates that the voltage wave resulting from a backflash may be approximated by a wave having a crest voltage of 1,600 kv and a time-to-half-value on the order of 10 microseconds. The stroke current magnitude used to arrive at these values was 200,000 amperes, the minimum value required to cause a backflash. The shortness of the tail is largely due to the fact the $L\,di/dt$ component of voltage at the struck tower is lost after the stroke current reaches its maximum. Also, the negative reflections over the ground wires from the adjacent towers help to reduce the length of tail. The reduction in magnitude to 1,600 kv is due to the coupling effects with the ground wire. Short-tail waves, waves number 2 and number 5 of Table I, are of this type.

Chopped Waves. Chopped waves result from strokes directly to the phase wire of sufficient magnitude to flashover the insulation to the tower. Such a stroke is a shielding failure or sideflash which is quite rare in view of the fact that shielding failures occur on modern high-voltage lines on only about 0.1 per cent of the total strokes to the line. A stroke current of 50,000 amperes is taken as the upper limit since that current is not capable of holding the tower top potential above 100 kv using the tower constants previously given.

The surge voltage on the phase conductor resulting from side-flashes having currents in the 10,000- to 50,000-ampere range therefore was taken as a chopped wave of essentially zero tail. The maximum value of this surge was taken as 2,000 kv. Chopped waves, waves number 1 and number 4 of Table I, are of this category.

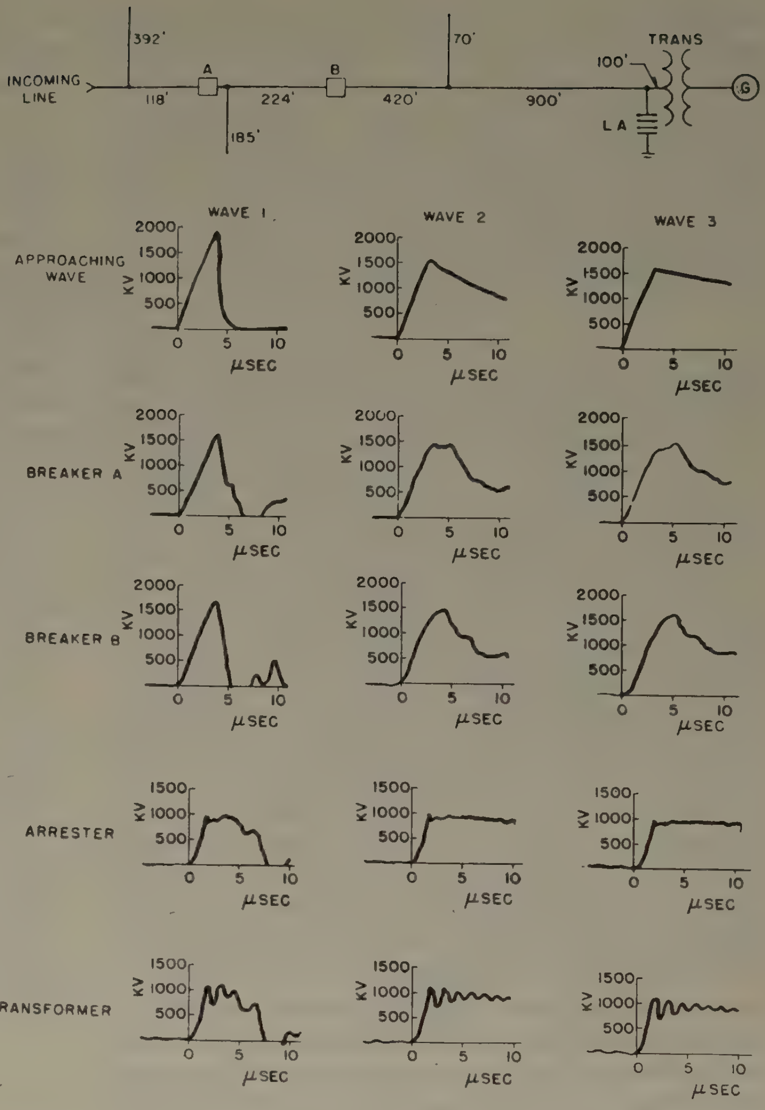

Figure 3. Typical oscillograms taken from the Anacom for the circuit of case I, Figure 2

Full Waves. Full waves are those created by side-flashes of such low current magnitude that the insulation does not flashover to ground, permitting a wave having a long tail to enter the substation. The magnitude of this surge is limited to the full wave insulation level of 18 insulators, or 1,600 kv. Full waves, waves number 3 and number 6 of Table I, are of this type.

Rate of Rise of Incoming Surges. Both corona and resistive losses tend to slope off the incoming waves as they approach the switching station. Two rates-of-rise were considered in order to bracket the range through which this quantity might reasonably vary, namely, 500 and 1,000 kv per microsecond. This brings the total number of incoming wave shapes considered to six which are summarized in Table I.

PROBABILITIES

ONE AIM OF the study was to estimate the probable frequency with which the circuit breakers in the station might be expected to flashover if lightning arresters were not installed at the circuit breakers. To arrive at this estimate it was first necessary to find, from lightning stroke probability data, the probable frequency with which each of the three types of waves just discussed may be expected to originate on any mile of the transmission line. Of course, unless the stroke occurs within a relatively short distance of the switching station, the incoming wave will be attenuated to a value which is harmless. Evaluation of what this distance is requires an estimate of the rate of attenuation and the amount of attenuation necessary to render the surge harmless. One purpose of the analogue computer study was to obtain the latter information.

Probability of Lightning Strokes. For the region in Indiana, Ohio, West Virginia, Kentucky, and Virginia in which much of the American Gas and Electric Company system is located, the isokeraunic level may be taken as 45 thunderstorm-days per year. This gives rise to an estimated 150 strokes per 100 miles per year to the transmission line, on which the following discussion is based.

Probability of Short-Tail Waves. These waves require a stroke current of 200,000 amperes or more if resulting from a backflash or of 50,000 amperes or more if from a sideflash. From probability data, it is found that strokes of more than 200,000 amperes constitute less than 0.1 per cent of all recorded stroke currents; those greater than 50,000 amperes, 10 per cent. However, of the strokes to the line not more than 0.1 per cent are expected to cause sideflashes, that is, to engage the phase conductor directly without engaging the ground wire. On the basis of 150 strokes per 100 miles per year to the transmission line, $150/100 \times 0.001 = 0.0015$ short-tail waves may be expected per year per mile of transmission line.

Probability of Chopped Waves. Lightning strokes with currents in the 10,000- to 50,000-ampere range are found from probability curves to make up 56 per cent of the total strokes. Since shielding failures occur for 0.1 per cent of the strokes to the transmission line, then it is found that $150/100 \times 0.56 \times 0.001 = 0.00084$ chopped waves will occur per year per mile of transmission line.

Probability of Full Waves. Lightning stroke currents of from 5,000 to 8,000 amperes occur for about 10 per cent of the total strokes. Since this wave also results from a sideflash, the probability of obtaining a full wave on a phase conductor is $150/100 \times 0.001 = 0.0015$ per year per mile of transmission line.

USE OF THE ANACOM

Because of the virtual impossibility of making the analysis by long-hand methods, the various station layouts with the six different approaching waves were studied on the analogue computer.

Anacom Setup. One phase of the 330-kv circuit between the generator transformer and the point where the transmission line enters the switching station was represented on the Anacom, a number of pi-sections being used to represent the distributed constants. According to standard computer practice, an appropriate time base was used to keep the frequencies of the computer circuits within a range where the losses would be low. Similarly, an impedance multiplier was used to fit the circuit constants to the computer.

The Anacom provides facilities whereby an oscilloscope may be used to measure the voltage between any desired points in the analogue circuit. Photographs were taken of all pertinent voltage waves obtained in this study in order to have permanent records.

Results From the Anacom. The Anacom study consisted of measuring the voltages at the various lettered points of the three switching station layouts shown in Figure 2 with varying values of the distance, denoted by *X*, between the station and the transformer and with the six different approaching voltage waves.

Twenty-four tests were made for case I, each of the six waves being applied for distances from station to transformer of 500 feet, 1,000 feet, 2,000 feet, and for an infinite distance. For each test, oscillograms were taken of the applied wave and the surge voltage at the circuit breakers, lightning arrester, and transformer (points *A-E* in Figure 2). Typical data from this group of tests are shown in Figure 3. There the oscillograms taken at four locations for each of three approaching waves are shown for the 1,000-foot spacing between the switching station and the transformer.

Similar measurements were made for the circuit of case

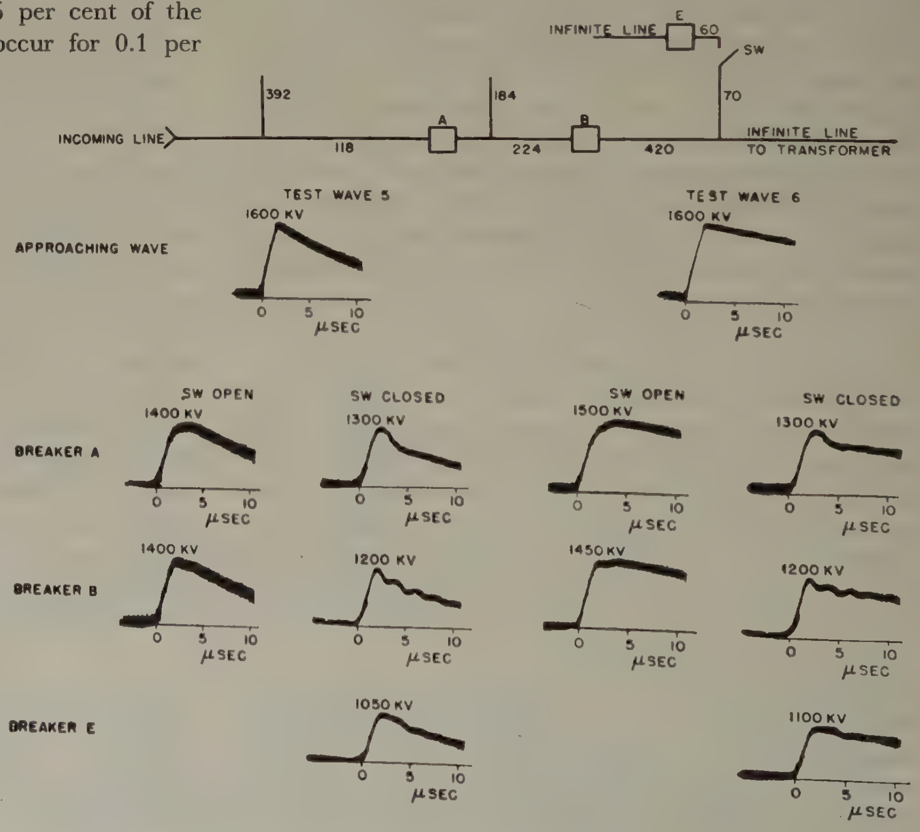

Figure 4. Oscillograms showing effect of a second feeder from the station

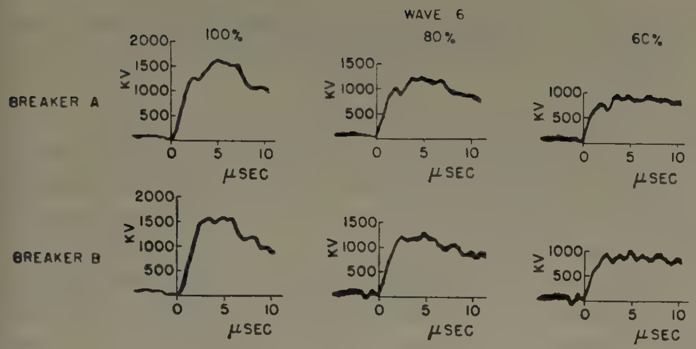

Figure 5. Oscillogram of voltage at the circuit breakers showing effect of reducing the magnitude of incoming voltage wave number 6 to 80 per cent and 60 per cent of its 1,600-volt crest. These data were taken for case II of Figure 2 with X=2,000 feet

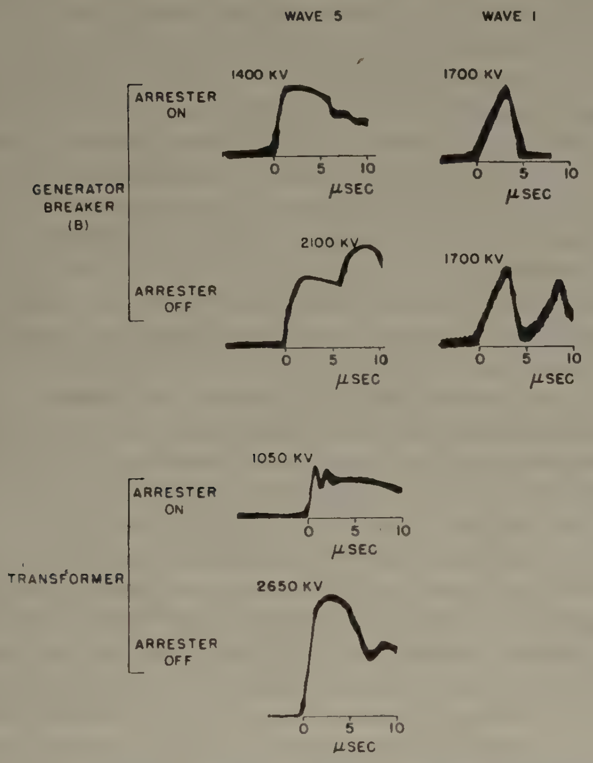

Figure 6. Voltages at circuit breaker B and the transformer with and without the lightning arrester at the transformer in operation. Data taken for case I of Figure 2 with X=2,000 feet

II, Figure 2, for distances of 500, 1,000, and 2,000 feet between the switching station and transformer, and for case III, Figure 2, for a 1,000-foot spacing.

Tests were made to show the effect of a second transmission line into the station. This was done by representing an infinite line connected to breaker *E* in case III, Figure 2. An infinite distance from the switching station to the transformer was used in this test since it was found to give the most severe voltages for case I. A direct comparison may then be made between the data for case I and for this test. Comparable oscillograms are shown in Figure 4.

To show the effect of incoming surges of reduced magnitudes, two additional tests were made using the circuit of case II with a separation distance of 2,000 feet. For these tests, full waves with crest magnitudes of 80 per cent and 60 per cent of 1,600 kv were applied. The resulting voltage waves appearing across the two circuit breakers are shown in Figure 5.

Several measurements were made at random to determine the effect of removing the lightning arrester from the circuit altogether. The data were taken for case I, Figure 2, for wave 1 and wave 5 with a 2,000-foot separation between the switching station and the transformer. The oscillograms are shown in Figure 6 where the crest voltages are indicated.

Analysis of Anacom Results. Insulation levels of electric equipment are expressed in terms of standard test waves; for example, the impulse withstand curves for the 330-kv bushings shown in Figure 7 are based on standard $1^{1}/_{2}$x40-microsecond waves. Oscillograms taken from the Anacom were analyzed on the basis that the circuit breakers used on the 330-kv system would have insulation equally as good as the curves of Figure 7.

Where nonstandard impulse voltages are encountered, considerable judgment is required to estimate whether the insulation of any particular equipment is suitably protected. One method of analysis which has been used consists of comparing the volt-time curve of the nonstandard wave with the impulse withstand curve.

This procedure does not permit benefit from the turn up of the impulse withstand curve at short values of time. As the surge voltages obtained in this study were of short time duration, it appeared that the proper recognition and employment of this characteristic of the insulation might result in considerable economic benefit.

In this analysis, the disruptive effect of nonstandard waves was expressed in terms of an equivalent standard wave with the integration method of Witzke and Bliss.[1] The calculated points shown by the crosses in Figure 7, indicate that the method gives results in close agreement with the withstand curve. Use of this method shows how the maximum economic use can be made of the insulation.

In this analysis an index termed the severity index is

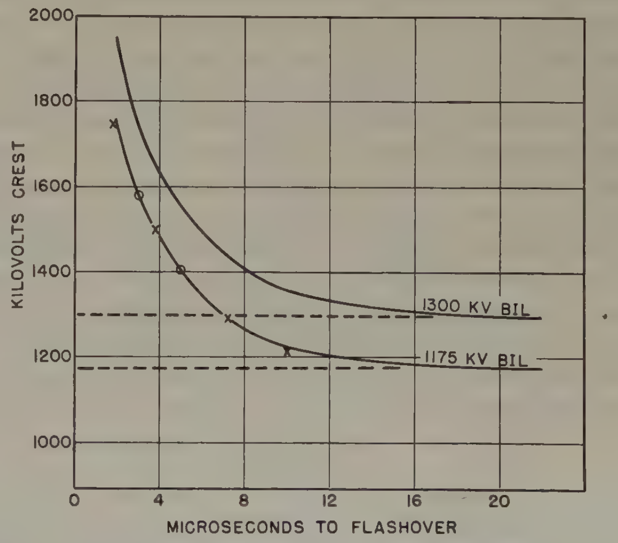

Figure 7. Impulse withstand curves for the circuit-breaker bushings with points calculated by the disruptive effect method

Table II. Per Cent Severity Index of Voltage Waves at the Circuit Breakers

Distance X, Feet	Circuit Breaker*	Wave 1	2	3	4	5	6
Case I							
500	*A*	91	96	104	78	92	104
	B	99	97	100	81	88	99
1,000	*A*	96	98	108	70	96	104
	B	97	98	101	79	98	105
2,000	*A*	91	102	110	74	96	108
	B	98	105	120	83	96	113
∞	*A*	93	100	119	83	100	129
	B	99	103	119	83	99	119
Case II							
500	*A*	100	86	94	71	82	92
	B	88		92	76	84	92
1,000	*A*	84	93	103	73	88	95
	B	93	95	96	76	82	96
2,000	*A*	76	103	114	95	96	110
	B	90	102	112	97	100	110
Case III							
	A	96	95	99	77	88	101
1,000	*B*	87	94	103	72	86	104
	E	107	98	99	88	93	102

* The letters *A*, *B*, and *E* refer to the same points on the circuit diagrams of Figure 2.

Table III. Per Cent Severity Index of Voltage Waves at the Circuit Breakers with Two Feeders Closed

Case III with second feeder closed to circuit breaker E. X = ∞

	Wave 5	Wave 6
Circuit breaker *A*	73	92
Circuit breaker *B*	75	85
Circuit breaker *E*	66	88

Table IV. Per Cent Severity Index for Voltage Waves at the Circuit Breakers with Reduced Incoming Waves

Case II, X=2,000 feet, Wave 6

	100 Per Cent Wave	80 Per Cent Wave	60 Per Cent Wave
Circuit breaker *A*	110	91	76
Circuit breaker *B*	110	92	82

used. The severity index of any given wave shape is defined as the peak voltage of a standard $1^1/_2$x40-microsecond wave which has the same disruptive effect as does the given wave. It is expressed in per cent of the peak voltage of the $1^1/_2$x40-microsecond wave which the insulation just withstands. Thus a nonstandard wave with a severity index of 110 per cent based on the 1,175-kv withstand curve stresses the insulation the same amount as does a $1.10 \times 1{,}175 = 1{,}290$-kv $1^1/_2$x40-microsecond standard wave. To prevent flashover of the 1,175-kv basic impulse insulation level insulation, the magnitude of the nonstandard voltage wave must be reduced, in this example, by $(110-100/110)100=9$ per cent.

The severity indexes for all of the oscillograms were obtained from the corresponding disruptive effect values and are tabulated in Tables II, III, and IV.

CONCLUSIONS

1. The Anacom is a very useful tool in studying the change in voltage characteristics within an extensive high-voltage station from lightning surges coming into the station from overhead transmission lines. Combined with the voltage-limiting characteristics of the line itself, such studies are useful in selecting the lightning protection within the station.

2. Lightning surges entering a 330-kv station are greatly modified in shape, and considerably in magnitude, at various locations within the station due to the distances involved, and tap leads to the main current-carrying conductor.

3. The more tap connections of appreciable length, the greater the reduction in the severity of the surge within the station.

4. On the 330-kv station studied, the need for lightning arresters close to the transformers (basic impulse insulation level=1,175), is clearly shown even in spite of the reduction in severity of surge voltages within the station. Where no arrester is used at the transformer, the voltage magnitude is appreciably increased above the incoming surge at the station entrance.

5. The volt-time characteristics of high-voltage insulation at short times can be used, in the light of this study, to reduce the required basic impulse insulation levels of costly equipment in the station, by taking advantage of the reduced severity of incoming voltage surges as they are favorably altered in shape by multiple tap connections of appreciable length.

6. Multiple transmission lines into a station reduce the magnitude of voltage surges, thus further decreasing the stress on station equipment.

7. A determination of a severity index obtained from the disruptive effect theory for much of the data obtained gives an idea of the probability of insulation failure when subjected to the various voltage wave shapes at locations in the station.

8. Also, the probability of different surge voltage wave shapes, as limited by line construction and insulation, entering the station, and their frequency of occurrence are useful in making a final choice of basic impulse insulation levels.

9. The final selection of basic impulse insulation levels for all equipment in a station must be made, in final analysis, on the basis of many factors including:

(*a*). Lightning protective level.

(*b*). Severity of surge voltage characteristics at the equipment, whether protected by lightning arresters or not.

(*c*). Probability of equipment failure with the protective scheme used.

(*d*). Frequency of damaging voltage occurrence.

(*e*). Cost of equipment repair against cost of more complete protection.

(*f*). Disruptive effect on the electric system as a whole, in case of failure, not only momentarily, but also until repairs are made.

(*g*). Reduction of impulse strength of equipment with years of service.

(*h*). Lightning arrester performance characteristics.

REFERENCE

1. Co-ordination of Lightning Arrester Location With Transformer Insulation Level, R. L. Witzke, T. J. Bliss. AIEE *Transactions*, volume 69, part II, 1950, pages 964–75.

Apparatus for Testing A-C Watt-Hour Meters

F. C. HOLTZ
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WITHIN THE PAST DECADE much attention has been directed to increasing both the accuracy and speed of testing and calibrating single-phase a-c watt-hour meters. The availability of high accuracy transfer instruments has made possible the measurement of alternating current to an accuracy of 0.02 per cent.

Such instruments, including all forms of dynamometer wattmeters, are a part of the procedure employed in the testing of single-phase a-c watt-hour meters which, for convenience, may be divided into three general classes as follows: 1. direct methods using indicating instruments and timing devices; 2. indirect or comparison methods using rotating standards; 3. methods using indicating instruments in which the measurement of time is not involved directly.

The first category has been applied generally in many different forms and the application of electronic tubes and photoelectric cells has made important contributions toward improving its precision. Because of certain inherent qualities of a-c watt-hour meters the accuracy of the final results will be influenced by the arrangement employed.

The second category includes most of the arrangements in general use today by the manufacturer and user alike. Here, the rotation of the meter under test is compared directly with another taken as a standard. In one form the meter under test is arranged to start and stop the rotating standard and the revolutions are compared directly. Unless considerable care is exercised the final result will be influenced by starting and stopping errors plus the possibility of slight errors resulting from the motion of the disk of the standard both immediately before and after the test. The ideal arrangement would be one in which both the meter under test and the standard would be running continuously and the revolutions over a given period compared directly. This is the object of stroboscopic testing.

In its application, however, the element of time enters which, together with the slight irregularities in meter disk rotation, introduces a number of difficulties. This is particularly true at low rotational speeds.

In an effort to remove some of these difficulties and provide a permanent record the author has employed an arrangement used quite extensively for determining the rate of time pieces.

The general arrangement shown schematically in Figure 1 may be described briefly as follows. The recorder comprises a synchronous motor-driven drum on the surface of which is disposed a spiral ridge whose pitch is equal to the axial length of the drum. A paper tape also driven by the motor through suitable reduction gears moves tangentially to, but out of contact with, the drum. Adjacent to the paper tape and parallel to the axis of the cylinder is a conventional typewriter ribbon. A solenoid-actuated printing bar is disposed adjacent to and parallel to the typewriter ribbon so that, when momentarily depressed, it will leave as a dot the momentary position of the spiral in relation to the paper.

In the present application the synchronous motor is driven by the rotating standard in the conventional manner. The printing bar is momentarily brought to bear against the drum through the discharge of a capacitor which occurs each time an anticreep slot of the meter under test permits light to enter a photoelectric cell as shown. When the meters are under continuous rotation a series of dots appear on the tape from which the accuracy of the meter under test with reference to the standard may be determined readily. This is done either by measuring the spacing of dots in a direction parallel to the axis of the drum or by means of a protractor. In the latter, the accuracies are determined by the angle which a succession of dots make with the direction of motion of the tape. Preliminary adjustment of the meter under test is accomplished by stroboscopic means as shown.

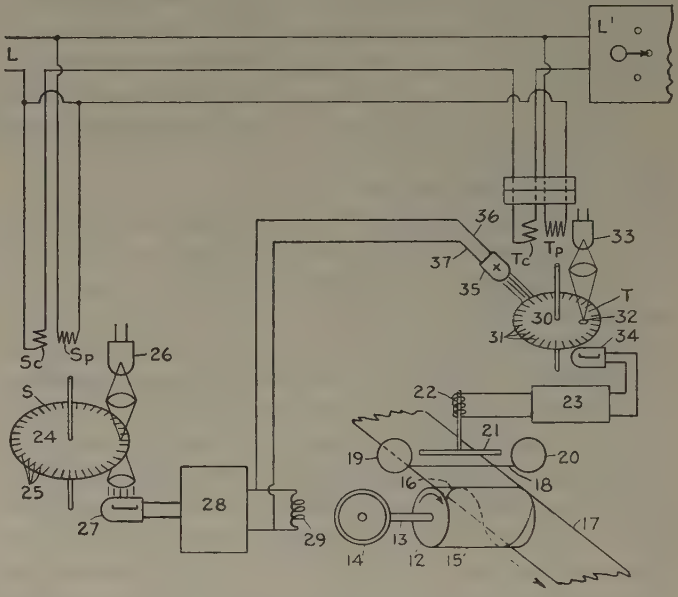

Figure 1. Line schematic diagram illustrating use of the watt-hour meter comparator

Under the third category, dynamometer wattmeters are arranged to control directly a frequency such that it is directly proportional to watts. The meter under test then directly controls a cycle counter from which its accuracy may be determined.

Digest of paper **52-56,** "Methods and Apparatus Employed in the Testing of Single-Phase A-C Watt-Hour Meters," recommended by the AIEE Committee on Instruments and Measurements and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 21–25, 1952. Scheduled for publication in AIEE *Transactions,* volume 71, 1952.

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The Vocabulary of the International Electrotechnical Commission

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The publication, in 1938, of an international vocabulary of electrical terms marked the first time that such a list of definitions had been produced upon which international agreement had been reached. Advances during and since World War II, however, have necessitated the current process of revision, work in which the United States, previously inadequately represented, is taking an active part.

THE International Electrotechnical Commission was founded as a result of the following resolution passed at the meeting of the International Electrical Congress, held in St. Louis, Mo., in 1904:

"That steps should be taken to secure the co-operation of the technical societies of the world by the appointment of a representative commission to consider the question of the standardization of the Nomenclature and Ratings of Electrical Apparatus and Machinery."

It was not until 1910, however, that the IEC appointed a Nomenclature Committee for the purpose of drafting an international list of terms and definitions relating primarily to electric machinery. At that time, both national and international standards were in their infancy and the Nomenclature Committee was embarking on pioneer work, and also at the time the importance of this work was not fully realized. The first list of terms was adopted at a plenary meeting in Berlin, Germany, in 1913. The work was resumed in Brussels in 1920 with the result that at the meetings held at The Hague in 1925 and at New York, N. Y., in 1926 the committee found it possible to agree on certain principles in drafting an international vocabulary. At the plenary meeting in Bellagio in 1927, decided progress was made when agreement was reached on the present system of classification into groups and sections and the system of numbering the groups, sections, and individual definitions.

The actual preparation of the definitions in IEC is conducted by Committee *1*, Nomenclature, the present chairman of which is General E. E. Wiener of Belgium. Also, the commission is constituted of national committees, one of which is organized in each representative country. Following 1927, meetings of Committee *1* were held once or twice a year to 1937; and through the efforts of the several national committees, as well as other international organizations, the work throughout this period progressed rapidly. In 1938, the present edition was published. It goes far beyond the early conception of limiting the definitions to electric apparatus and machines. There are 14 groups, or major categories, divided into about 100 sections, and there is a total of nearly 2,000 terms including general and fundamental terms as well as those associated with apparatus and machinery. The terms are defined in the two official languages, French and English, and each definition is accompanied by its title translated into German, Italian, Spanish, and Esperanto.

This edition has served admirably as an authoritative reference of electrical terms; but its one great accomplishment has been that for the first time the national committees of the several countries had become a unified working group able to produce a vocabulary of definitions of electrical terms on which international agreement could be reached.

Among the handicaps under which this first vocabulary had been prepared was the lack of adequate representation on the part of the United States. The burden of the representation, as well as the leadership in advancing the project, were carried by Dr. C. O. Mailloux and Dr. Arthur E. Kennelly. However, as able and industrious as these two men were, it was impossible for them to be authorities in the details of the large number of definitions involved in the numerous fields included in the 14 groups and their several sections, and, moreover, no two persons could possibly find the time which such an involved activity requires. At the present time, however, the United States is taking a much more active interest in the current revision of the vocabulary.

NECESSITY FOR REVISION

A FEW YEARS after the 1938, or first, edition of the vocabulary had been published it was realized that it could be profitably improved and expanded. As has already been pointed out, it was a pioneer project with no previous experience to guide it. Moreover, as with the "American Standard Definitions of Electrical Terms," the tremendous advances in science and engineering during and after the war had correspondingly increased the number of new electrical terms. Hence, at the meeting of the IEC in Stresa, Italy, in 1949, it was voted to proceed with the revision. At this and subsequent meetings, the definitions were divided into 21 groups and the national committee of each of the different countries was entrusted with the preparation of certain of these different groups. In Table I are given the group number and title, and the national committee to whom the preparation of the several groups is entrusted.

It will be noted that the numbers of the different groups

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Table I. Division of Definitions

Number	Title of Group	National Committee
05	Fundamental Definitions	France
07	Electronics	Unsted States
08	Electroacoustics	Italy
10	Machines, Transformers, and Mutators	France and Sweden
11	Transductors	Sweden
12	Relays	Sweden
15	Switchboards and Apparatus for Connection and Regulation	Italy
20	Apparatus for Scientific and Industrial Measurements	France
25	Production, Transmission, and Distribution of Energy	Italy
30	Electric Traction	France
31	Signalling and Other Safety Apparatus for Railways	France
35	Electromechanical Applications	Switzerland
37	Servomechanisms	United Kingdom
40	Electroheating Applications	Norway
45	Lighting	Switzerland
50	Electrochemistry and Electrometallurgy	United States
55	Telegraphy, Telephony	United Kingdom
60	Radio Communications	United Kingdom
65	Radiology	United States
70	Electrobiology	United States

are, almost without exception, different from those of corresponding groups in the "American Definitions of Electrical Terms." Also, in some instances, subjects included within one American group are subdivided among two or more of the international groups. For example, Electroacoustics, Transconductors (Magnetic Amplifiers), Telegraphy, Telephony, Radio Communication, and Wave Guides are all included within the single American group, Electrocommunication, but each is a separate group in the international definitions. On the other hand, in the American definitions, Transformers, Regulators, Reactors, and Rectifiers, and also Rotating Machinery, are each a separate group, whereas in the International definitions, Machines, Transformers, and Mutators (Rectifiers) are a single group. In the American definitions, the general definitions of relays are given in the group, Switchgear, and special types and applications are defined in other groups with which they are associated. In the international definitions, relays are all included in a single group, and so on. However, the American definitions have groups not included in the IEC vocabulary, such as Transportation (Land, Marine, Air); Electric Welding and Cutting; Mining; and Miscellaneous, although the IEC does include Electric Traction.

UNITED STATES' CONTRIBUTION

The United States is entrusted with the preparation of four groups, Electronics, Electrochemistry and Electrometallurgy, Radiology, and Electrobiology. This responsibility falls directly on the United States National Committee (USNC), of which Dr. Harold S. Osborne is president and J. W. McNair is secretary. As the USNC is affiliated with the American Standards Association, the machinery through which this work is done is the same as that used in national standardization. For nomenclature and definitions this means that the work is carried on by Sectional Committee *C-42* and its subcommittees which currently are engaged in the revision of the "American Standard Definitions of Electrical Terms." Moreover, the chairman of Committee *C-42* is a technical advisor to Committee *1* (Nomenclature) of the IEC and accordingly is the official United States representative on that committee and hence shares in formulating its general policies. The chairmen of the subcommittees of Committee *C-42* are also technical advisors to IEC Committee *1* and hence are eligible to contribute to the preparation of IEC definitions. Also, Mr. McNair, in addition to being secretary to the USNC, is the secretary of the Electrical Standards Committee of ASA which has general responsibility for the work of ASA electrical standardizing committees of which *C-42* is one. Accordingly, there is a very close interlocking between Committee *1* of IEC, the USNC, and ASA Committee *C-42*, so that the last-named committee becomes not only the natural but the official United States agency directly responsible for United States participation in the definition activities of the IEC.

When the United States was entrusted with the preparation of four groups of the vocabulary it was most appropriate, as well as convenient, to request the chairman of the appropriate *C-42* group to assume the responsibility. S. B. Ingram of the Bell Telephone Laboratories and chairman of *C-42* Subcommittee *14:* Electronics, has submitted to IEC the *07* group; and Dr. G. W. Vinal (retired) of the Bureau of Standards and chairman of *C-42* Subcommittee *12:* Electrochemistry and Electrometallurgy, has submitted to IEC group *50*: Electrochemistry and Electrometallurgy. Dr. M. D. Schulz of the Massachusetts General Hospital, chairman of *C-42* Subcommittee *15:* Radiology, and Dr. F. T. Jung, chairman of *C-42* Subcommittee *16:* Electrobiology, both have nearly completed their groups of definitions which are to be submitted shortly to IEC.

However, in addition to the different individual countries being entrusted with the initial preparation of one or more groups of definitions, all countries having membership in IEC share the responsibility of bringing all the definitions to their ultimate approved form. Accordingly, after the national committee of a country has submitted to the IEC the group of definitions with which it is entrusted, the definitions are reproduced in the two official languages, French and English, the corresponding terms in the two languages being arranged in two parallel columns. These reproductions then are circulated through the several constituent countries for review and, after the lapse of a reasonable time, meetings of so-called "preparatory subcommittees" are held, to discuss and come to agreement if possible on the group under consideration. The membership of a preparatory subcommittee is made up of delegates from the several constituent countries. It may be necessary to hold more than a single meeting of a subcommittee before a group can be brought to the status in which it is ready for approval.

During the past summer a meeting of the IEC was held early in July in Estoril, a seaside resort on the coast of Portugal, about 15 miles from Lisbon. Committee *1* as a whole met on two occasions during the week to discuss and arrange general policies and to determine the time schedule of the several groups. During most of the period, there were meetings of the Preparatory Subcommittee, *07:* Electronics; and *10:* Machines, Transformers, and

Mutators. United States delegates on Subcommittee *07* were Dr. H. S. Osborne, J. W. McNair, and Professor C. L. Dawes. United States delegates on Subcommittee *10* were H. R. Arnold, Dr. H. S. Osborne, and C. F. Wagner.*

Because both France and England proposed to submit for consideration a substantial number of additional terms yet to be defined, and because it became necessary to make arrangements with other groups, such as Illumination and Radiology, as to which groups certain terms which were more or less overlapping in their scope should be assigned, it was decided that another meeting of Preparatory Committee *07* would be necessary. It was possible, however, to bring nearly to completion the draft of Group *10*, which has been under consideration for a longer period than *07*, so that, with some minor and editorial changes, it could be translated and finally approved.

The next meeting of the IEC which may include Committee *1* will be held at Scheveningen, Netherlands, in September 1952. Before that time other groups of definitions will be circulated among the several countries for review and meetings of several of the preparatory subcommittees are to be held at Brussels during May. Hence, the work is progressing quite satisfactorily.

AMERICAN AND IEC DEFINITIONS

IT IS OBVIOUS that the foregoing system of organization brings the United States and IEC committees preparing definitions into very close relationship and facilitates the attaining of agreement between corresponding American and IEC terms. Moreover, during the present revision, the subcommittees of Sectional Committee *C-42* have consulted the IEC definitions in preparing their own and, whenever possible, have brought the two into agreement. Likewise, in the current revision of the IEC vocabulary, the several IEC subcommittees have had access to the revised *C-42* definitions and have taken them into consideration. However, it is not always possible to bring all definitions of the same terms into agreement, although frequently the differences are only in the wording. The United States revision began some time before the IEC one, and it was impracticable to delay many of the groups until the corresponding IEC groups had been completed. Also, much apparatus and many practices in the United States are quite different from international ones, so that, under the circumstances, the definitions must be different.

Representation by the United States in the international meetings on definitions involves a substantial amount of time and expense as most of these meetings must be in Europe. It is important to have at these meetings men who are thoroughly competent in the fields to be discussed and preferably men who are active on the American committees dealing with these groups of definitions. Although General Wiener has most considerately offered to schedule such meetings to meet the convenience of United States delegates, it is not easy to secure adequate United States representation at all the meetings. Each country does have the privilege of submitting written comments, but experience shows that this is far less satisfactory than personal representation in which the prevailing differences of opinion can be resolved by personal discussion.

In spite of the time and expense involved, the interest of American industry and other organizations in this country has led them to respond favorably to requests to assign members of their organizations to attend most of the group meetings, including several members of Committee *C-42* and others. In addition, United States experts already have submitted many written comments and suggestions. Hence, the United States is contributing much more actively and systematically in the preparation of the second edition of the IEC vocabulary than it was able to do with the 1938 edition.

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* Other United States delegates to the IEC meetings of other committees were V. L. Cox, C. W. Falls, C. M. Lafloon, E. F. Seaman, R. C. Sogge, Vice-Admiral G. F. Hussey, and W. C. Wagner. See "Progress on International Agreements," *Standardization*, November 1951, page 354.

Revision Status of American Standard Definitions of Electrical Terms

C. L. DAWES
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AFTER SOME 20 years of preparation, the first edition of the "American Standard Definitions of Electrical Terms" was issued in 1941. The scope is defined as: "Defining correlation of definitions and terms in existing standards." The objective is to express for each term the meaning which is generally associated with it in electrical engineering in the United States. The desirability, in fact the necessity, for a glossary of this character hardly need be emphasized. Precise and authentic definitions of electrical terms are highly essential in the art and practice of electrical engineering, in scientific

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In answer to numerous queries, the author indicates briefly the procedure which is being followed, the large number of factors which must be taken into consideration, and the possible publication date of the current revision of the American Standard Definitions of Electrical Terms.

publications and textbooks, specifications, contracts, and other legal documents, as well as in litigation. Such a glossary fulfills for electrical engineering the function of an authentic English dictionary and it is intended to be the ultimate authority in the definition of any electrical or related quantity.

In view of the rapid and extensive developments in science and technology which were taking place even before this first edition was issued, and which were greatly accelerated by the war effort, it became apparent that this first edition fell far short of including the many new terms which had come into being and the many new developments had so changed the scope and meaning of many of the existing terms that their definitions were either inadequate or no longer valid.

Hence, almost immediately after the end of the war, in 1946, the AIEE Standards Committee authorized the revision of the "Definitions," the AIEE continuing as sponsor, and the writer was appointed chairman of the American Standards Association Sectional Committee *C-42* under whose direction the contemplated revision was to be made.

CO-OPERATING ORGANIZATIONS

The chief purpose of ASA is "to provide systematic means by which organizations concerned with standardization work may co-operate in establishing American Standards in those fields in which engineering methods apply, to the end that duplication of work and the promulgation of conflicting standards may be avoided." This, in effect, means that in the preparation of an American Standard, all organizations having any substantial interest in the subject matter of any standard under preparation or revision should be represented. There is certainly no electrical standard that is so far-reaching into so many different fields as this glossary of electrical definitions.

Moreover, it is very important that when a term is defined, every possible usage be taken into consideration. Hence, in the organization of the Sectional Committee every effort was made to include within its membership representatives of all organizations who might have any material interest in electrical terms and quantities and their applications. In addition to the several scientific, engineering, and manufacturing organizations which are represented, many government agencies are included such as The Bureau of Standards, Bureau of Mines, the Army, the Navy, and the Air Force, and the Canadian Standards Association and Mexico each has a liaison representative.

The Sectional Committee is the authoritative body which is responsible for the project, and the definitions must be approved by it before they become official.

The committee has appointed 18 subcommittees, each responsible for one category, or group, of definitions. Each subcommittee has a chairman who is responsible for the work of the subcommittee. He appoints the members of his subcommittee and may organize it in any manner which he sees fit. For example, some subcommittees have vice-chairmen and secretaries. Also, it is common practice to assign the work of certain sections, such as mathematics, units, nucleonics, to individual members who may be specialists in these fields. The different subcommittees and their chairman are as follows:

Group No.	Subcommittee	Title	Chairman
05	1	General (Fundamental and Derived) Terms	J. D. Tebo
10	2	Rotating Machinery	E. B. Paxton
15	3	Transformers, Regulators, Reactors, and Rectifiers	J. E. Clem
20	4	Switchgear	H. J. Lingal
25	5	Control Equipment	G. W. Heumann
30	6	Instruments, Meters, and Meter Testing	F. B. Silsbee
35	7	Generation, Transmission, and Distribution	A. A. Johnson
40, 41, 42	8	Transportation	H. C. Griffith
41,	Section 10	Air Transporation Subgroup	K. R. Smythe
45	9	Electromechanical Applications	Sterling Beckwith
50	10	Electric Welding and Cutting	R. W. Clark
55	11	Illuminating Engineering	H. Reinhardt
60	12	Electrochemistry and Electrometallurgy	G. W. Vinal
65	13	Communication	E. I. Green
70	14	Electron Tubes	S. B. Ingram
75	15	Radiology	Dr. M. D. Schulz
80	16	Electrobiology including Electrotherapeutics	Dr. F. T. Jung
85	17	Mining	E. J. Gleim
95	18	Miscellaneous	R. L. Lloyd

It is not only important that all phases of electrical applications be represented on the Sectional Committee, but it is equally important that the members of the subcommittees be recognized authorities in the several fields which are represented. The wide representation which is necessary is better understood when it is realized that electric power and phenomena have invaded nearly every field of engineering and scientific endeavor. For example, electric power is actively employed in such fields as land, sea, and air transportation, illumination, electrochemistry and metallurgy, radiology, electrobiology, and mining, none of which in itself is electrical engineering. Consequently, among subcommittee members may be found automotive, nautical, aeronautical, mining, and illumination engineers; electrochemists; physicists who are authorities in light, radiation, X rays, and gas discharges; X-ray specialists who are expert, some in the physical aspects of radiology; and doctors of medicine who are expert in the applications of electricity to electrotherapy and electrobiology. In fact, in these last two fields we could have accomplished little without having obtained assistance from the American Medical Association, an organization which seems far removed from electrical engineering. Through its co-operation we have obtained the services of Dr. M. D. Schulz and Dr. F. T. Jung as chairmen of the Subcommittees on Radiology and Electrobiology.

It is almost needless to point out that innumerable quantities, other than electrical, are measured by electrical means, so that the field of electrical measurements is a horizontal one of great breadth, extending well into the fields of nearly every science such as physics, chemistry, metallurgy, geology, and into nearly all the fields of engineering such as mechanical, chemical, and mining. This illustrates, I believe, the wide representation that is necessary in a single subcommittee such as the one which has prepared the definitions on electric instruments and meters.

The science of electrical engineering depends to a large extent on mathematics, and, as is well known, many special mathematical techniques particularly adapted to electrical phenomena have been developed. Hence, in the preparation of the definitions, we have been obliged to seek the assistance of mathematicians and the American Mathematical Society is represented on the Sectional Committee of the ASA.

It is well known that since the 1941 edition, the fields of electronics and wire and radio communication have expanded tremendously and the new terms to be defined have increased correspondingly. The definitions of these terms have been greatly facilitated by the close co-ordination which has been developed between our subcommittees and the standardizing committees of the Institute of Radio Engineers and we are greatly indebted to the IRE for the support which it has given this project.

In very recent years there have developed several entirely new fields and new techniques such as magnetic amplifiers, servomechanisms, nucleonics, and electronic, digital, and analogue computers. With fluorescent and other new types of luminants, the field of illumination now extends deep into the fields of gas discharges, fluorescence, and radiation so that extensive representation in the field of physics was highly necessary. Acoustics has reached well into the electrical field and in the electrical definitions, on account of the overlap, it is difficult to know where to delineate between electroacoustical and purely acoustical terms.

The foregoing discussion is intended to show the wide scope and the large number of fields of engineering and science which the definitions embrace, and also the large number of authorities in these several fields whose services we have been obliged to enlist so that the definitions may be complete as well as authoritative. We are all indebted to the several subcommittee chairmen and the members whose time is necessarily valuable, but yet who give freely of their time and effort in order that an authoritative encyclopedia of electrical definitions may be made available to all who wish to use it.

Credit for the work should go also to H. E. Farrer, formerly secretary of the AIEE Standards Committee and the *C-42* Committee, whose experience and advice has been most helpful; to J. J. Anderson, secretary of the AIEE Standards Committee and the ASA *C-42* Committee, who carries the usual secretarial burdens; and to J. W. McNair, secretary of the Electrical Standards Committee, ASA, who has general supervision and co-ordination of this work.

STATUS OF PRESENT REVISION

WITH SO MANY new terms hitherto not defined, no one questions the need and desirability, as well as the importance, of having these definitions made available at once. The chairman and secretary have employed every means available to them to expedite the work and bring out the definitions early in published form. However, the process of preparing the definitions is necessarily slow. There must be several meetings of most of the subcommittees whose members usually are widely separated, there must be co-ordination with the several AIEE and ASA committees on standards. Comparisons are made with the definitions in the Vocabulary of the International Technical Commission in the attempt to make alike, wherever possible, the definitions of corresponding American and international terms. There is quite a large amount of intracommittee correspondence, and it takes time even in a single subcommittee to reach agreement on many definitions whose scope or meanings have not as yet become clearly defined. Also, the work is being performed on a voluntary basis by men who hold responsible positions and it is gratifying that with their regular duties they can devote so much time to this time-consuming activity.

At the present time all but a few of the subcommittees have completed their first draft. These several drafts already have been circulated for review among the Sectional Committee members, the AIEE technical committees, and among those subcommittee members and others who have requested opportunities to examine specific groups.

These drafts thus have been widely reviewed and a vast amount of correspondence relating to proposed changes has passed to and among the several subcommittees. Among the different groups inevitably there have been duplications and the definition of a particular term by one subcommittee may not take into account all its applications in other fields. The assignment to particular groups of duplicate terms and agreement over the final wording of definitions, taking into consideration the scope of each, is practically completed among the different subcommittees. Also, each subcommittee has about completed the revision of its definitions in accordance with the comments that have been received from the many reviewers, and hence it now should be in its final form. This final revision of each group then will be submitted to the members of the Sectional Committee for their approval.

With comprehensive representation on each subcommittee, which includes organizations represented on the Sectional Committee, and the fact that wide circulation has just been completed, it is hoped that the completed revisions will be approved promptly. Shortly thereafter they should be available, in some form, for general distribution.

Evaluating Single-Phase Induction-Motor Parameters

F. W. SUHR
MEMBER AIEE

THE SO-CALLED MOTOR CONSTANTS of primary and secondary resistances, primary and secondary leakage reactances, and the magnetizing reactance, as well as iron and friction losses of single-phase induction motors, are derived from considerations obtained from standstill and no-load tests. Having reliable values for these circuit parameters enables the designer to make accurate calculations of motor performance.

Primary resistances R_1 and R_{1_s} of the main and auxiliary phase windings vary with the temperature of the windings. They should be corrected to an arbitrary base temperature. They are directly measurable. The secondary resistance R_2 referred to the main phase primary likewise varies with temperature, and should be corrected to the arbitrary base. Assume R_2 changes the same percentage as R_1. Of greater interest and importance is the change of R_2 with frequency, even for shallow bars. Use an assumed equation

$$R_2=R_\epsilon+R_\sigma[1+k(f'/f)^n] \tag{1}$$

where R_ϵ and R_σ are the end ring and bar components respectively at zero frequency, f is the rated frequency, f' is any frequency from zero to twice rated, and k and n are determined from test. Solution of the equation is obtained from standstill impedance tests at rated, half-rated, and twice-rated frequency.

Primary leakage reactances X_1 and X_{1_s} of the main and auxiliary phase windings decrease with increased winding currents due to saturation of leakage flux paths. With the auxiliary phase winding in the top of the slot $X_{1_s}<X_1$.

The magnetizing reactance X_m referred to the main phase primary decreases after the main flux paths begin to saturate. At low voltages X_m is linear, but at near rated voltages it may deviate. Increased load current causes primary voltage drop that tends to desaturate the flux paths.

For all of these parameters to be treated as the simultaneous mathematical entities they are, tests for their separation must be designed to this end.

The voltage induced in the auxiliary phase at synchronous speed is given by

$$\boldsymbol{E}_{s0}=a\frac{\boldsymbol{I}_0}{2}\,\frac{X_m^2}{(R_{24}/2)^2+(X_m+X_2)^2}\quad[(X_m+X_2)+j\,R_{24}/2] \tag{2}$$

where a is the ratio of main phase to auxiliary phase effective turns, R_{24} is the effective double frequency value of R_2, and $\boldsymbol{I}_0$ is the main phase current.

$$\boldsymbol{I}_0=\frac{V_0}{R_1+\left[\dfrac{X_m^2(R_{24}/4)}{(R_{24}/2)^2+(X_m+X_2)^2}\right]+ i\left[X_1+\dfrac{X_m\{(R_{24}/2)^2+(X_m+X_2)(X_m/2+X_2)\}}{(R_{24}/2)^2+(X_m+X_2)^2}\right]} \tag{3}$$

Equations 2 and 3 become useful tools in themselves, but when used with the special device termed "j/a amplifier" still more useful data can be obtained. When $-\boldsymbol{E}_{s0}/a$ is applied to the wattmeter potential coil (negligible current is drawn from the auxiliary phase), and $\boldsymbol{I}_0$ flows in the wattmeter current coil, then the meter reads: real part of $-\boldsymbol{E}_{s0}/a\,\boldsymbol{I}_0={}_0W_0$ vars. It is shown that

$${}_0X_0={}_0W_0/I_0^2=\frac{{}^1/{}_2X_m^2(X_m+X_2)}{(R_{24}/2)^2+(X_m+X_2)^2} \tag{4}$$

Again using the same device, but applying $j\boldsymbol{E}_{s0}/a$ to the potential coil with $\boldsymbol{I}_0$ in the current coil, the wattmeter reads: real part of $j\boldsymbol{E}_{s0}/a\,\boldsymbol{I}_0={}_yW_0$ watts. It is shown that

$${}_0R_{2b}/2={}_yW_0/I_0^2=\frac{X_m^2R_{24}/4}{(R_{24}/2)^2+(X_m+X_2)^2} \tag{5}$$

Again using the same device, but applying $j\boldsymbol{V}_0$ to the potential coil with $\boldsymbol{I}_0$ in the current coil, the wattmeter reads: real part of $j\boldsymbol{V}_0\boldsymbol{I}_0=W_{0x}$ vars. It is shown that

$$W_{0x/\boldsymbol{I}_0^2}=X_0=X_1+\frac{X_m/2[(R_{24}/2)^2+(X_m+X_2)(X_m+2X_2)]}{(R_{24}/2)^2+(X_m+X_2)^2} \tag{6}$$

If these three measurements are repeated with the auxiliary phase considered the main phase, with the main phase considered the auxiliary phase, and with the auxiliary phase current I_{s0} made equal to I_0/a, values of ${}_0X_0'$ and X_0' corresponding to ${}_0X_0$ and X_0 are obtained. Actually curve data should be taken over a voltage range.

By making the assumption that the auxiliary phase primary reactance X_{1_s} is proportional to X_1, $X_{1_s}=k_qa^2X_1$. A complete separation of all parameters is possible from synchronous speed readings. The important part of this procedure is to determine X_m at various degrees of saturation. It is necessary to use an unsaturated value of X_m for standstill tests. At standstill the main phase current is

$$\boldsymbol{I}_z=\frac{\boldsymbol{V}_z}{\left\{R_1+\dfrac{X_m^2R_{22}}{R_{22}^2+(X_m+X_2)^2}\right\}+j\left\{X_1+\dfrac{X_m[R_{22}^2+X_2(X_m+X_2)]}{R_{22}^2+(X_m+X_2)^2}\right\}} \tag{7}$$

where $\boldsymbol{V}_z$ is the applied main phase voltage, and R_{22} is the effective rated frequency value of R_2.

With $\boldsymbol{I}_z$ flowing in its current coil and $\boldsymbol{V}_z$ applied to its potential coil a wattmeter will read

$$W_z=\text{real part of }\boldsymbol{V}_z\boldsymbol{I}_z\text{ watts or }W_z/I_z^2=R_1+\frac{X_m^2R_{22}}{R_{22}^2+(X_m+X_2)^2} \tag{8}$$

With $j\boldsymbol{V}_z$ applied to the potential coil, the meter will read

$$W_x=\text{real part of }j\boldsymbol{V}_z\boldsymbol{I}_z\text{ or }W_x/I_z^2=X_1+\frac{X_m[R_{22}^2+X_2(X_m+X_2)]}{R_{22}^2+(X_m+X_2)^2} \tag{9}$$

Now repeating these tests using the auxiliary phase winding and using currents $I_{sz}=I_{z/a}$ and also equation 6, X_1, X_2, and R_{22} can be determined based on our knowledge of the unsaturated value of X_m.

Digest of paper 52-48, "Toward an Accurate Evaluation of Single-Phase Induction-Motor Constants," recommended by the AIEE Committee on Rotating Machinery and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 21–25, 1952. Scheduled for publication in AIEE *Transactions*, volume 71, 1952.

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Analyses of Subsequent Faults

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RENEWED INTEREST IN resonant neutral grounding[1] makes it important to have available methods for predicting accurately voltages and currents under abnormal system conditions. A-c network analyzer methods utilizing symmetrical component and 3-phase principles are used for the analysis of subsequent faults on power systems, often called simultaneous faults. Included are systems so grounded that a single line-to-ground fault is not a short circuit. Faults are imposed on two sections of line at x and y, see Figure 1. This selection is general and does not place any restrictions on the location of the chosen line sections which, for example, may be portions of radial feeders at opposite ends of a general network. They may be portions of lines connecting two general networks in any manner, or may be simpler and more familiar configurations.

The general method of sequence network connections is based entirely upon symmetrical components and requires simultaneous representation of all three networks. No restrictions are placed on the values of sequence impedances, and all loads and generators may be included. One fault is represented by an ordinary series connection of the networks, but because of voltage and current restrictions and dissymmetry, isolating transformers and 120-degree phase shifts must be used for the second fault.

With Clarke components, the α and zero networks are identical to the positive- and zero-sequence networks respectively, while the β network differs only by its generated voltages from the negative-sequence network. The first fault requires a series connection of the α and zero networks, and half the zero impedances; the second requires coupling transformers.

By utilizing the superposition principle whereby the component methods are modified to make provision for switching faults on and off the system, the separate effect of each fault may be obtained.

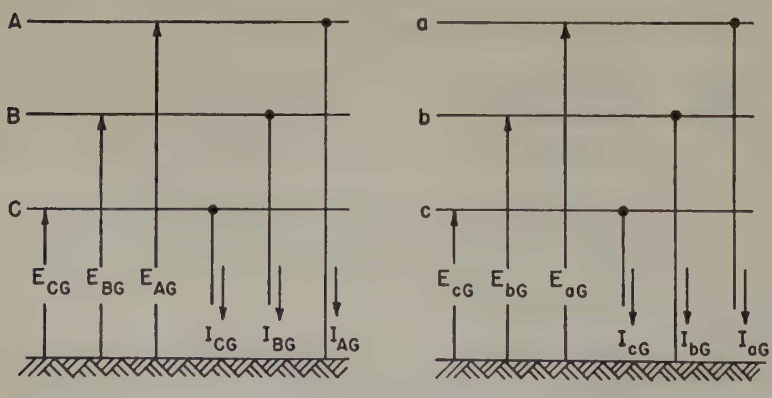

Figure 1. Subsequent faults at locations x (left) and y (right) of a symmetrical 3-phase system

The difficulties of phase shifts are obviated by the equivalent Y. In this method, an equivalent Y between the faulted points and neutral is obtained for the negative- and zero-sequence networks. These circuit constants then are combined into an equivalent which is inserted in the positive-sequence network. The modified equivalent Y is very similar except that each fault is represented by a single impedance connected in parallel with the positive-sequence network at the point of fault.

It is sometimes possible and more practical to use 3-phase methods for fault studies. The 3-phase and neutral and 3-phase and zero-sequence methods assume the positive- and negative-sequence networks to be identical, electromotive forces excepted.

In the 3-phase and neutral method, a 3-phase 4-wire circuit represents each branch, with necessary forcing transformers to insure correct current flows. Power transformers may be represented by actual transformer banks or, in some cases, by simple series impedances. Generated voltages are represented by balanced 3-phase electromotive forces. Faults are imposed by making the actual connections. Line and residual currents and line-to-line and line-to-ground voltages may be measured directly.

The 3-phase and zero-sequence method differs from the preceding one in that the zero-sequence current and voltage are confined to a separate network. Fault connections are not quite so simple, but correct current distribution is obtained without forcing transformers. Directly measured may be line-to-line, line-to-ground, and zero-sequence voltage, and residual current.

In general, the component methods are more applicable to larger systems. However, they are more time-consuming for system quantities are all obtained by calculation. The equivalent Y method is most desirable when studying a large complex system, since only one sequence network need be set up at one time.

The 3-phase methods are to be preferred for they have the very desirable advantage of direct reading of phase quantities. The relatively large number of required network-analyzer units usually limits their application to small networks, with only one or two equivalent generators.

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Planetary Position Effect on Short-Wave Signal Quality

J. H. NELSON

A new approach to an as yet unsolved problem is the observance of planetary effects on transatlantic short-wave radio signals. Correlation over seven years shows that certain planetary arrangements agree well with the behavior of short-wave signals.

AT THE Central Radio Office of RCA Communications, Inc., in lower Manhattan, an observatory housing a 6-inch refracting telescope is maintained for the observation of sunspots. The purpose of erecting this observatory in 1946 was to develop a method of forecasting radio storms from the study of sunspots. After about one year of experimenting, a forecasting system of short-wave conditions was inaugurated based upon the age, position, classification, and activity of sunspots. Satisfactory results were obtained, but failure of this system from time to time, indicated that phenomena other than sunspots needed to be studied. The first article[1] by the author on this subject appeared in March 1951; the current article is in part a review of that article, and in part will submit additional evidence supporting deductions made at that time.

STUDY OF PLANET POSITIONS

CYCLIC variations in sunspot activity have been studied by many solar investigators in the past and attempts were made by some, notably Huntington,[2] Clayton,[3] and Sanford,[4] to connect these variations to planetary influences. The books of these three investigators were studied and their results found sufficiently encouraging to warrant correlating similar planetary interrelationships with radio signal behavior. However, it was decided to investigate the effects of all the planets from Mercury to Saturn* instead of only the major planets as they had done. The same heliocentric angular relationships of 0, 90, 180, and 270 degrees were used and dates when any two or more planets were separated by one of these angles were recorded.

Investigation quickly showed there was positive correlation between these planetary angles and transatlantic short-wave signal variations. Radio signals showed a tendency to become degraded within a day or two of planetary configurations of the type being studied. However, all configurations did not correspond to signal degradation. Certain configurations showed better correlation than others.

Considerable study was devoted to the most severe degradations and led to the discovery that when three planets held a "multiple of 90 degrees" arrangement among themselves, the correlation was more pronounced. These arrangements were called "multiple configurations" and exist when two planets are at 0 degree with each other and a third planet is 90 degrees or 180 degrees away from them. Also, a multiple exists when two planets are separated by 180 degrees with a third planet 90 degrees from each. These multiples are quite common. A more uncommon type of multiple is the case where all three planets are at 0 degree with each other. From the few cases recorded, this type of multiple shows the least correlation.

Many of the multiples are completed in the space of a few hours, being accompanied by sharp severe signal degradation. At other times, the multiple may take several days to pass, being accompanied by generally erratic conditions during the period. The time needed to complete the multiple depends on the relative speeds between the three or more planets involved. These multiples show correlation for plus and minus about 5 degrees from the exact arrangements previously mentioned.

Configurations of this type actually can be considered as cycles and when several cycles peak at the same time there should be maximum effects. The records for 1948, 1949, and 1950 indicate that such has been the result. Specific instances are demonstrated in Cases 1 to 9 in Table I. Since consistency of data is of paramount importance in an article of this type, the same cycles between the same three planets have been selected. We may refer to these arrangements as multicycles.

All the close multicycles made between Mercury-Venus-Jupiter were extracted from the records of 1948, 1949, 1950

Table I. Multicycles Among Planets Affecting Radio Signal

Cases	Dates	Time Consumed	Results in Signal Degradation
1	Feb 23/48	1 day	Severe 23d and 24th
2	Apr 18–22/48	5 days	Severe 19th to 22d
3	June 19–23/48	5 days	Slight 19th to 22d
4	Aug 18–21/48	4 days	Slight 19th to 21st
5	Oct 15/48	1 day	Very severe 14th and 15th
6	Apr 12/49	1 day	Very severe 11th to 13th
7	Oct 6–8/49	3 days	Very severe 7th and 8th
8	Apr 2–5/50	4 days	Very severe 1st to 6th
9	Sept 28–Oct 1/50	4 days	Very severe 30th to 4th*
10	Sept 21–23/51	3 days	Extremely severe 20th to 26th**

* A multicycle between Mercury-Earth-Mars came on 5th and 6th. The degradation continued through to October 7.

** Three complete multicycles took place during this period involving Mercury, Venus, Jupiter, Saturn, and Uranus.

Revised text of a conference paper recommended by the AIEE Subcommittee on Energy Sources and presented at the AIEE Winter General Meeting, New York, N. Y., January 21–25, 1952.

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* J. H. Clark of Press Wireless Inc., New York, N. Y., has found that Uranus, Neptune, and Pluto also show correlation. Mr. Clark has been correlating planetary positions and short-wave signal behavior using the methods given in the author's original article.

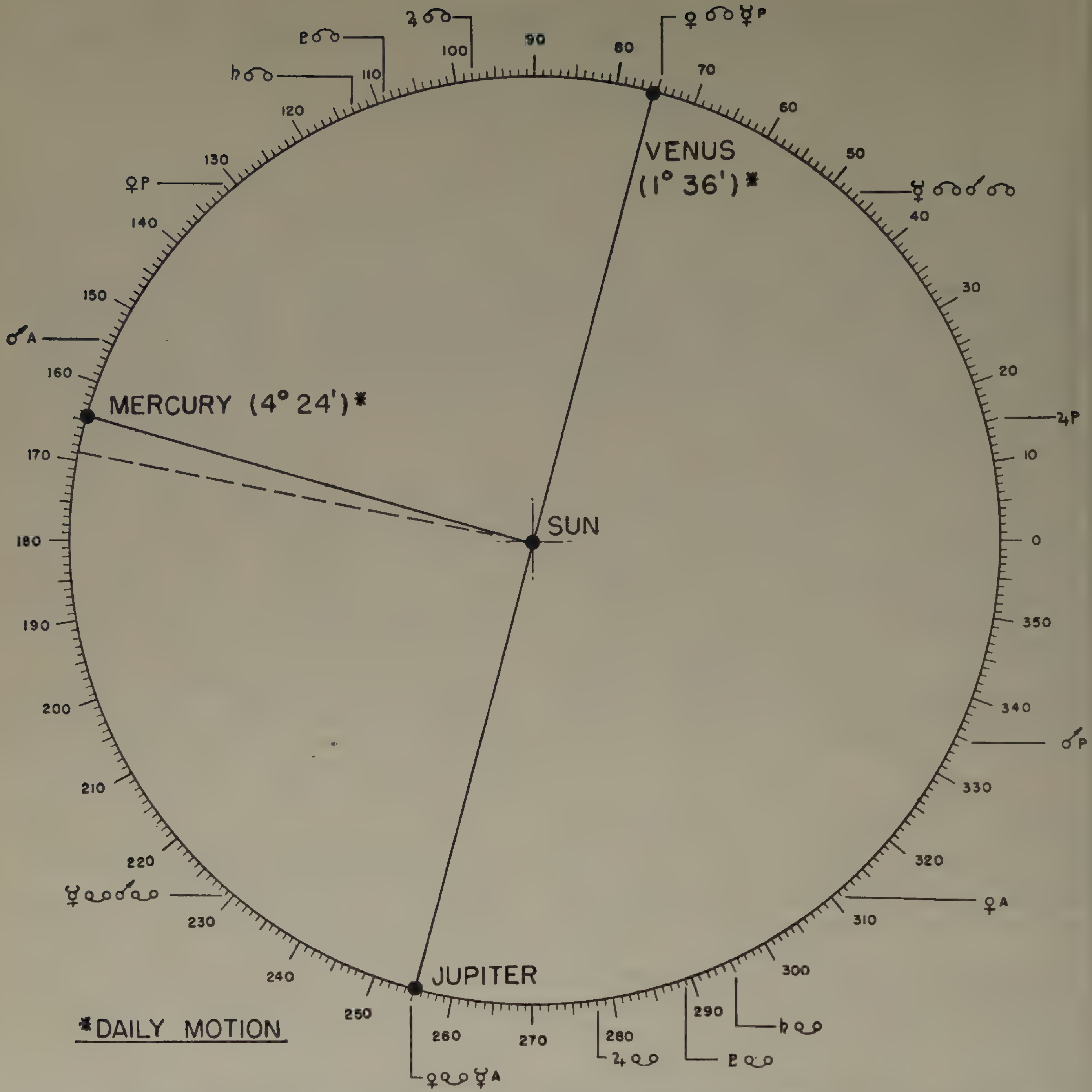

Figure 1. The heliocentric arrangement of Venus, Mercury, and Jupiter on February 23, 1948, which resulted in severe signal degradation on that day and the one following

and correlated with existing radio conditions. Multicycles for these three planets were found in nine cases which are listed in Table I. Case 10 is a triple multicycle that coincided with an extremely severe signal degradation in 1951. The heliocentric arrangements of the planets involved are shown in Figures 1 and 2 for Cases 1 and 10.

Single configurations (one cycle) between only two isolated planets show the least correlation, but often when several single cycles between several isolated planets coincide in time the correlation is quite pronounced. Most of the single cycles, however, do correlate with at least slight signal degradation. Some correlate with severe degradation.

At times, two, and sometimes three, complete multicycles occur in the space of a few days. At other times a multicycle will occur mingled with one or more single cycles between other planets.

Theoretically, if these planetary arrangements do have the effect that correlation indicates, the cycles between the slow planets should have gradual long-term effects establishing an over-all standard. The most degraded periods should come as the faster planets come into cycle with them or among themselves.

Jupiter and Saturn, the largest planets in the solar system, are the most important. Due to their great size and slow motion, they can exercise the predominating

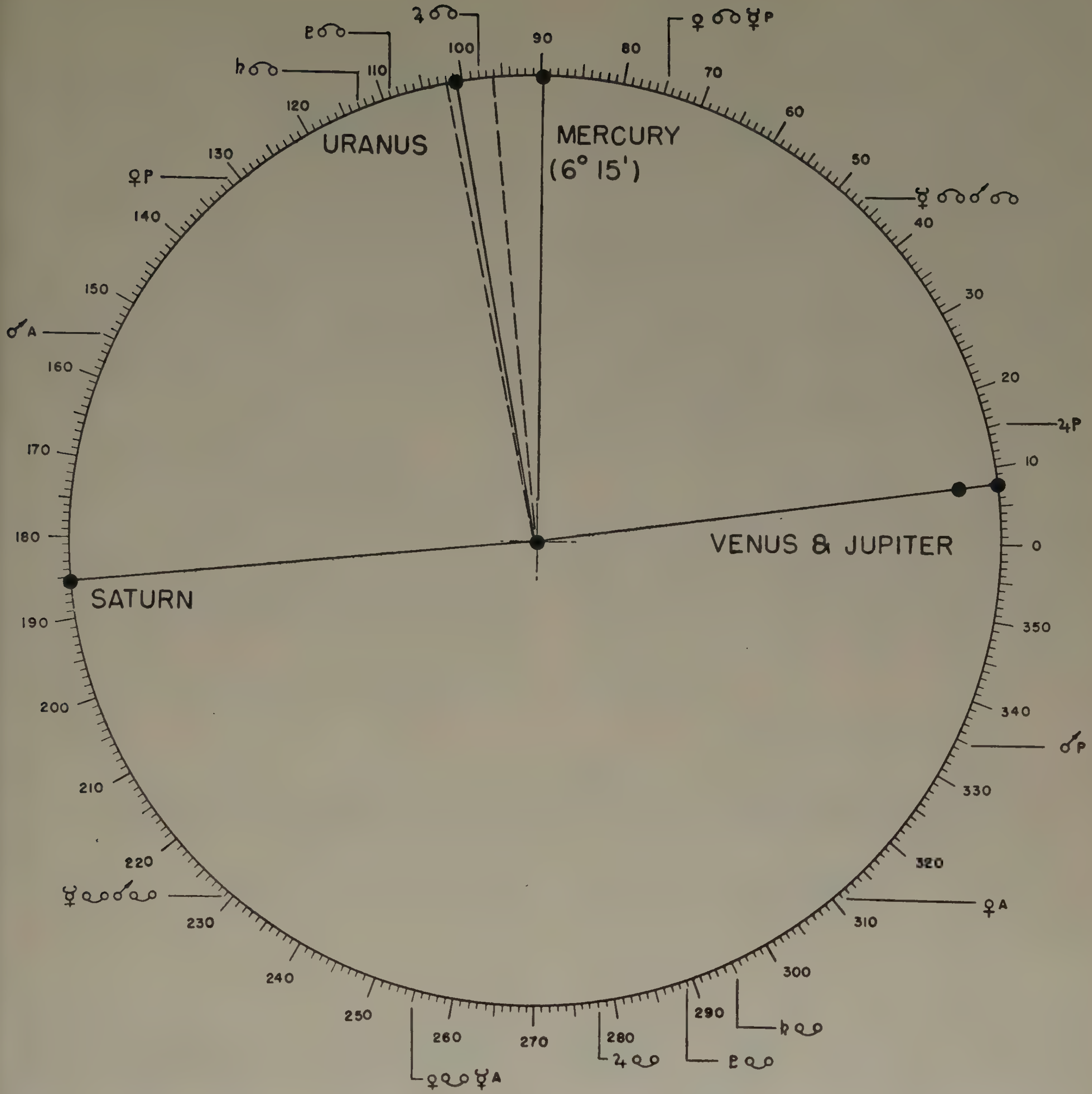

Figure 2. The heliocentric arrangement of the five planets shown which resulted in extremely severe signal degradation from September 20 to 26, 1951

influence on the sun for prolonged periods of time and therefore establish an over-all standard of disturbed or quiet conditions. However, the arrangements of the other slow planets can add to or take away from their effectiveness to some extent. Therefore, when Jupiter and Saturn are spaced near any multiple of 90 degrees, we should find the most degraded years with a high percentage of the radio disturbances severe.

The year 1951, which was a very degraded year, is an example of this. A slow planet multiple existed between Jupiter, Saturn, and Uranus with Jupiter and Saturn at nearly 180 degrees and Uranus almost 90 degrees from each. This arrangement set a low standard for 1951 and even normally weak cycles between isolated planets showed an effect. The radio disturbances were prolonged and severe. This multiple between these three slow planets permitted a great increase in fast planet multiples and semimultiples. A semimultiple took place each time a fast planet cycled with Jupiter, Saturn, and Uranus successively within a few days. This happened frequently in 1951.

The records indicate that when Jupiter and Saturn were spaced by a multiple of 60 degrees, radio signals were of better quality than when spaced by multiples of 90 degrees. Under such an arrangement there are fewer multicycles. During such years a high percentage of the single cycles show no important correlation except on the normally weaker circuits. Only the stronger groups of cycles are then accompanied by significant degradation.

It is worthy of note that in 1948 when Jupiter and Saturn were spaced by 120 degrees, and solar activity was at a maximum, radio signals averaged of far higher quality for the year than in 1951 with Jupiter and Saturn at 180 degrees and a considerable decline in solar activity. In other words, the average quality curve of radio signals followed the cycle curve between Jupiter and Saturn rather than the sunspot curve.

When all nine planets of the solar system are considered, we find a great many multicycles and individual cycles which would make correlation very difficult if these cycles were evenly spaced in time. However, the cycles are not evenly spaced, there being a general tendency for the cycles to occur in groups. There are, however, exceptions to this at times.

CONCLUSION

THE AUTHOR chooses to look upon this hypothesis of a planetary-positions effect upon the quality of shortwave signals as a new approach to the problem and it should be considered as one more tool with which a researcher might work. A tremendous amount of work needs yet to be done.

The correlation found between signal degradations and these planetary arrangements in the past has been sufficiently consistent to indicate that under these arrangements, particularly in the case of multicycles, the planets possibly influence the sun in such a manner as to cause a temporary change in its radiation characteristics. The ionosphere of the earth is apparently particularly sensitive to these changes and reacts accordingly.

By combining planetary indications with solar observations and a day-to-day signal analysis, a 24-hour forecasting system has been developed which averaged close to 85 per cent accuracy throughout 1950 and 1951 as reported by RCA Communications at Riverhead, L. I., N. Y.

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Application of Motors to Household Refrigeration Compressors

L. C. PACKER
MEMBER AIEE

Modern refrigeration demands a motor-compressor unit of long life, which will operate over long periods with little or no attention with high efficiency. To achieve this end, the designer of the hermetically sealed motors used today must take into consideration a number of factors peculiar to this application.

THE FIRST mechanical compressor for household refrigeration consisted of a pump which was belt-driven by an electric motor. There were shaft seals in the pump to prevent the refrigerant and oil from escaping. The belt and shaft seals were troublesome. Manufacturers did their best to make as good a box, and the mechanism as quiet, efficient, and free of vibration, as was possible at that time. However, with all its shortcomings, the housewife welcomed this type of refrigeration in preference to the old ice box.

One major step in solving these problems was the development of the hermetically sealed unit into which was assembled the pump, motor, refrigerant, and oil. This design made it possible to eliminate belt, shaft, and seal, and thus provide more space in the box for food per unit area of floor space. Less maintenance is required because of elimination of the belt and shaft seal and by sealing all working parts. The complete unit is also quieter, has less vibration, and can be manufactured at a lower cost than the belt-driven unit.

The hermetically sealed unit is a mechanical, electrical, and chemical unit which poses many problems, and which has taxed the ingenuity of mechanical, electrical, chemical, metallurgical, welding, manufacturing, and tool engineers. Today, as a result of their co-operation, the industry can point with pride to the great progress made in the art of making hermetically sealed refrigerators for the household,

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Essential text of paper 52-69, "Application of Motors to Household Refrigeration Compressors," recommended by the AIEE Committee on Domestic and Commercial Applications and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 21–25, 1952. Scheduled for publication in AIEE *Transactions*, volume 71, 1952.

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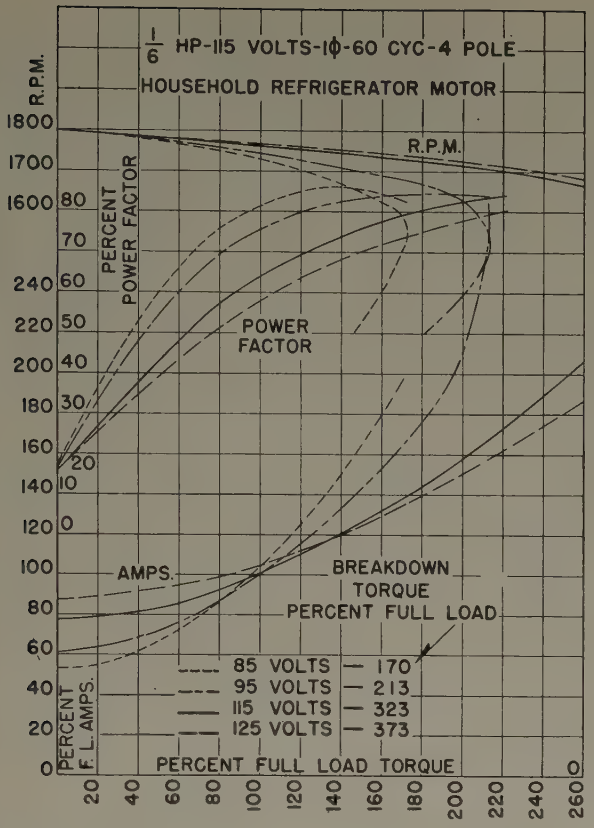

Figure 1. Current, power factor, and speed versus per cent full-load torque for various voltages; 1/6-horsepower 115-volt 1-phase 60-cycle 4-pole household refrigerator motor

as well as for commercial use. Professional artists have an important part in the styling of the cabinets.

The trend is for larger refrigerators on the same floor space. This means that the larger food space and frozen-food compartments will require better insulation and more efficient refrigeration units. Less space is also available for the motor and compressor.

It is not within the scope of this article to discuss the complete motor design for household refrigerators, but it is necessary in making a successful motor application for the motor engineers to know (1) the type of motor best suited for the application, (2) the power requirements and performance under all load and voltage conditions, (3) how the motor is to be started, (4) the maximum permissible motor temperatures, (5) that the motor is properly protected from overheating, (6) the chemical reactions that take place with various materials in the complete sealed unit, (7) the mechanical design of the motor and the materials necessary to satisfy the application, (8) the importance of mechanical, as well as chemical, cleanliness, (9) the compressor design in so far as it affects the assembly of the motor, and (10) the possible causes of motor failures in service which will not only be of considerable value to the motor designer, but also to the designers of the compressor and the other electric equipment.

MOTOR TYPES

NEITHER d-c nor repulsion-type motors are applicable to hermetically sealed compressors because of the commutator and sparking at the brushes. A-c motors of the squirrel-cage rotor type can be designed and built to handle almost any range required, except for exceptionally wide ranges of voltage.

Most household refrigeration systems are of the capillary tube type. Once a unit has stopped, it takes three to five minutes for the suction and discharge pressures to equalize, thus requiring a relatively low starting torque to start the compressor and get it up to speed and keeping the starting current within permissible limits.

The motors for household refrigerators are usually of the single-phase 4-pole 60-cycle 1,725-rpm type with split-phase starting. Ratings vary from one-tenth to one-quarter horsepower. However, the horsepower rating does not mean much, as the motor is designed for specific compressor applications. There may be instances where it is desirable to use a capacitor start motor to obtain more starting torque, but capacitor start motors seldom are used in household service.

Practically all of the 50-cycle and 25-cycle circuits in the United States have been changed over to 60 cycles. Domestic motors need only to be rated at 115 volts 60 cycles. The export trade requires 115, 200 to 250 volts, 50- and 60-cycle motors. The most economical motor design for domestic use may not be satisfactory for 50-cycle operation. Reactors and transformers are available to use with standard 115-volt 60-cycle domestic units to operate on most of the voltages and frequencies encountered in export trade.

POWER REQUIREMENTS

THE MOTOR that drives the compressor must be considered as an important part of the refrigerator system and not an accessory. It must be adequate to drive the compressor to obtain the required amount of refrigeration. It must have sufficient starting and accelerating torque to start and accelerate the load, and have sufficient breakdown torque to handle the maximum load at the lowest practical voltage at the terminals. The motor also must operate at a satisfactory temperature under operating conditions for the required life and at an efficiency to give low operating cost consistent with the initial investment under the practical minimum and maximum voltage conditions.

Voltages as low as 70 and as high as 130 found in some districts is too great a range for satisfactory operation of the motor. A motor to meet these conditions would be excessively large and lead to excessive cost for it and the compressor. It is more economical and more satisfactory from a performance standpoint to design the motor for a working range of 100 to 125 volts.

Figures 1, 2, and 3 show the performance plotted against per cent full-load torque for a refrigerator motor for an excessive range of 85 to 125 volts. Since the temperature rise of the winding varies approximately with the square of the current, it can be seen that it will rise very rapidly with increase in load at low voltages. The stator copper loss also reflects the variation in current. The total losses include stator-copper and rotor-cage losses, iron, and friction losses. The breakdown, starting, and accelerating torque varies approximately with the square of the voltage

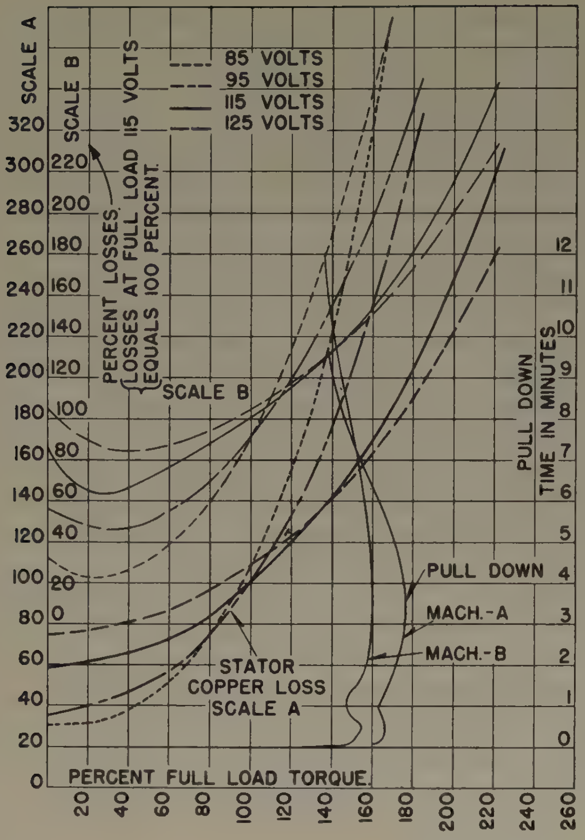

Figure 2. Total losses, copper losses, and pulldown time versus per cent full-load torque for various voltages. Motor specifications as for Figure 1

which means that at 85 volts the torque is approximately half of the torque at 115 volts.

The pulldown curves show the approximate torque and time required to pull down the temperature of the cabinet of typical refrigerators to a satisfactory value to preserve food. These particular curves have not quite reached the desired cabinet temperatures. Some cabinets require more and some less torque for the pulldown.

If the starting and running torques were fixed values for a given compressor, the selection of the proper motor would be a simple matter. The load of a particular compressor design varies as a function of (1) the refrigerant, (2) the suction pressure, (3) the discharge pressure, and (4) the degree of superheat. Of these, the last three may vary continuously during the operation of the refrigerator, and the range over which they vary may be different with each different unit to which the compressor is applied. The fundamental considerations in applying motors to hermetically sealed systems are no different than to open systems from a power standpoint.

MOTOR STARTING

A single-phase motor will not start without some auxiliary starting means. From a practical standpoint, it is necessary to wind into the stator core a starting winding displaced 90 electrical degrees with respect to the main or running winding. The combination of both windings produces sufficient torque to start and bring the load up to a predetermined speed. The starting winding is then cut out and the main winding takes the load on up to speed. The starting winding is usually cut out at a speed just above the breakdown-torque point of the main winding. If the load should become excessive, arrangements can be made to pick up the starting winding at a point below the breakdown torque of the main winding and take the load up to speed again because the torque of the combined main and starting winding is greater than that of the main winding only. Operation of this type of motor for short periods under heavy pulldown conditions at acceptable minimum voltages is permissible. However, too frequent operation under these conditions is detrimental to the life of the motor, contacts of the relay, and the protective device.

It is not permissible to have any transfer switching means such as centrifugal switches inside of the hermetic unit because of the inherent sparking; therefore, relays of various types must be mounted outside of the compressor for closing and breaking the starting-winding circuit. These relays may be of the current type, the time-delay or hot-wire type, or the voltage type.

The *current-type relay* is used in many household refrigerator applications. The current coil is placed in series with the main winding, and so designed that after the line switch is closed, it will close the contacts at a voltage below the minimum voltage on which the motor is expected to start and run. The motor starts and accelerates the load and at a predetermined speed the armature of the relay drops out, opening the contacts, thus disconnecting the starting winding. If the load becomes excessive and

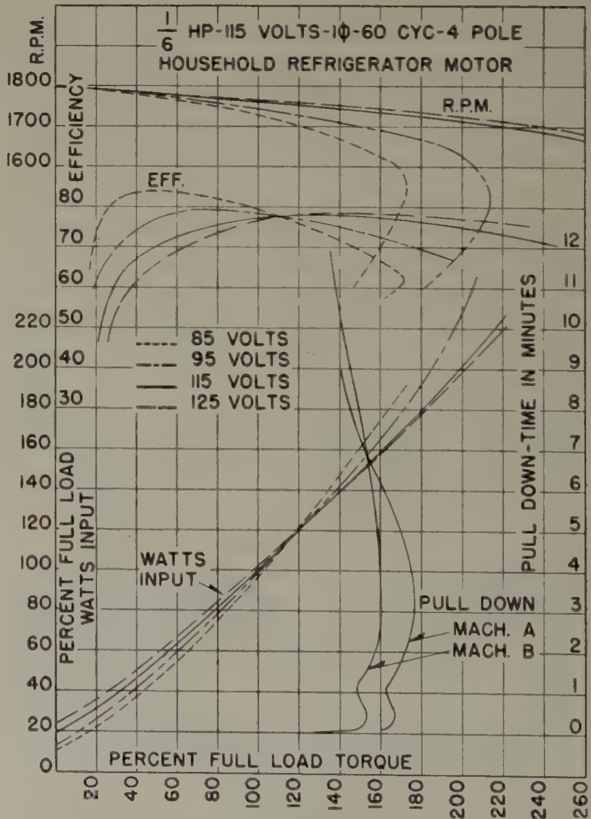

Figure 3. Watts input, efficiency, speed, and pulldown time versus per cent full-load torque for various voltages of motor specified in Figure 1

the speed drops below the breakdown torque of the main winding, a point is reached where the current increases to the closing current value of the relay. The relay armature picks up, closes the contacts, and connects the starting winding into the circuit to take the load up to speed again. This type of relay has been very successful.

Time-delay relays of the thermal type also are used in many household refrigerator applications for opening the starting-winding circuit. One very common such type is known as the hot-wire relay. The timing is such that it will open the starting-winding circuit under the worst condition of load and voltage which may occur. Normally, the time is longer than necessary to get the motor up to speed. Although this may cause some noise in coming up to speed, this type of relay, too, has been very successful.

The *voltage-type relay* normally has the contacts closed. The motor design must be such that the voltage across the auxiliary or starting winding will increase appreciably with speed. The increased voltage moves the relay armature to open the contacts. This type of relay can be used only with capacitor-start motors. The voltage change in the starting winding of a split-phase motor is inherently not sufficient to operate this type of relay successfully.

In order to have successful operation of the electric system, it is necessary to select the relays carefully to meet the characteristics of the particular motor involved.

MOTOR TEMPERATURE

THE TEMPERATURE of the motor and compressor parts are closely related because of their proximity. The presence of circulating oil and a relatively dense gas adds to the problem of temperature exchange between these closely related parts. This is particularly true with the small sizes of compressors and motors.

Heat is generated in the motor due to the losses in the motor. Heat is also generated in the compressor by the compression of the refrigerant and by the friction in the common bearing.

The heat must be dissipated from the complete motor-compressor unit; this may be done by radiation and convection, conduction through the compressor mountings and connections, and flow of gas through the compressor. Fins on the shell of the compressor or forced circulation of air by fans will increase the dissipation of heat from them.

It is well known that a temperature differential is necessary to produce a flow of heat to the point of dissipation of the heat. The flow of heat is proportional to the temperature differential, which causes various temperatures in the various parts of the motor, pump, and housing. Instances are known where the differential between the motor and pump temperatures was too great, and with large decreases in motor loss, its temperature decreased very little because of the heat flow from the pump into the motor. Therefore, it would be ideal in the construction of the complete compressor unit to have a heat barrier between the motor and the pump so as to have poor conduction between them, but have good conduction of heat from each to the outer shell. Circulating the oil properly in the housing will help to transfer the heat to the outer shell. Providing means for circulating the cool incoming gas through and over the motor will greatly assist in carrying away the heat due to motor losses.

Moisture in the sealed refrigeration system is harmful in numerous ways, causing both electrical and mechanical troubles. All organic materials slowly deteriorate at normal temperatures, giving off water. This decomposition increases in rate with an increase in temperature. The products formed by the decomposition of cellulose at excessive temperatures consist of approximately 35 per cent water, 39 per cent carbon, and the balance in gaseous and scattered products.

In a hermetic system, this decomposition seems to start slightly above 200 degrees Fahrenheit and increases at a somewhat higher rate than in air at higher temperatures. Overheating, even for short periods, should be avoided in hermetic motors even more so than in open motors where the products can escape to the atmosphere. Because overheating causes the liberation of moisture, it is difficult to examine a system which has failed and determine with any degree of certainty the original cause of the failure. It is not known whether there was excessive moisture present when the unit was manufactured or whether it was produced by the decomposition of the insulation. Even certain mechanical failures result in overheating, with the same end result. This makes it extremely difficult to analyze field returns and determine corrective measures necessary.

PROTECTION FROM OVERHEATING

OVERHEATING of a hermetic motor, as well as any motor, may be caused by overloading, undervoltage, overvoltage, or stalling of the motor. Abnormal ambient temperature, failure of the ventilating system, and, in some cases, loss of refrigerant, also contribute to overheating. Hermetic motors also receive some heat from the pump. The motor does not receive a constant amount of cooling and the temperature rise of the winding over the air temperature does not vary as the square of the current. In some compressor designs, the temperature rise decreases with increase in load due to gas cooling.

The inherent overheating type of protection protects the motor against various causes of overheating. In this type of protection, as applied to hermetic motors, it is assumed that the temperature differential between the motor winding and the protector location varies approximately as the square of the current. This temperature differential is relatively small when the motor is running.

An inherent overheating protective device consists fundamentally of a heating element mounted near a temperature-responsive element. The assembled unit is mounted on the compressor-motor shell so that the temperature-responsive element responds to a combination of the heat from the compressor shell and the line current through the heating element. This gives protection during running conditions. During stalled or extremely heavy loads the heavy current through the heating element causes the temperature-responsive element to open the line circuit to the motor even though the compressor shell temperature is low. The present types of inherent protective devices in use fully protect the starting windings against all conditions except welded relay contacts. The starting winding is wound with high-resistance wire and its current density is so high that the temperature rises many times faster than the main winding. One of the present remotely mounted types of relays, the hot-wire type, also will protect the starting winding under all conditions except welded relay contacts.

A protector should be selected to give satisfactory ultimate trip and locked-rotor protection to the running winding without nuisance tripout during the pulldown cycle and temporary overloads such as ice freezing. At the same time, it must protect the starting winding under all running and stalled conditions.

CHEMICAL REACTIONS

As previously stated, the motor and all compressor parts are completely enclosed in a shell which also serves as a reservoir for the refrigerant and as a crankcase for the lubricating oil. The complete hermetic unit must operate satisfactorily for a long period of time without attention. Therefore, the materials in the various parts must not undergo any appreciable change during this time. This includes all of the metals involved, lubricating oil, and all motor insulation.

Most household refrigerators now use Freon-12 or Freon-114 refrigerant, but whether it is sulphur dioxide, methyl-chloride, or Freon-12, there are corrosive effects which have been found by laboratory tests to occur in both wet and dry refrigeration systems; however, the chemical reaction is much greater in wet systems and more so in the methyl-chloride system. During World War II, there was very little Freon-12 available for refrigeration systems, and should a similar occasion arise in the future, it may be necessary to use another less critical refrigerant if refrigerators are to be made. Therefore, the following information which is based on 24 hours exposure at 125 degrees centigrade may be of some interest to the motor and refrigerator manufacturers.

Methyl Chloride—Dry Systems. There is no chemical reaction with steel, copper, brass, and phosphor bronze. Aluminum decomposes. Cotton chars and paper insulation chars and becomes brittle. Oil darkens if cotton is immersed in it.

Methyl Chloride—Wet Systems. Steel is corroded black and collects copper plating. Aluminum corrodes and becomes a fire and explosive hazard. Copper, brass, and phosphor-bronze corrode. Cotton and paper insulation char. Paper insulation and enamel on wire become brittle. Oil darkens if cotton is immersed in it. The chemical reaction on cotton and paper in dry methyl chloride is greater than the other systems and the addition of a small amount of water causes the corrosive action to be particularly bad. It has been found that it takes a smaller amount of water in methyl-chloride systems to accelerate chemical reaction than in other systems.

Sulphur Dioxide—Dry Systems. There is no reaction with steel, aluminum, copper, brass, phosphor-bronze, or paper insulation. Cotton insulation turns brown. Enamel wire is attacked and the oil darkens.

Sulphur Dioxide—Wet Systems. Steel corrodes black. Copper, brass, and phosphor-bronze corrode. Cotton insulation blackens and paper insulation deteriorates and becomes weaker. Enamel on the wire is attacked and the oil darkens.

Freon-12—Dry Systems. There is no reaction with any of the materials mentioned.

Freon-12—Wet Systems. There are traces of corrosion on steel, and a white discoloration on aluminum. Copper and brass have a black discoloration. No reaction with phosphor bronze. Cotton and paper insulation show a slight deterioration. Enamel wire and oil are not attacked.

Magnesium must not be used in any of these refrigerants mentioned.

It is imperative that all materials be as clean chemically as possible, and that there be no extractable materials present that will react to cause corrosion or deterioration.

A very small amount of moisture may be present because it is not possible to obtain a completely anhydrous condition in a refrigeration system. However, both assembly and dehydrating practice must be closely controlled to keep the moisture within limits which will not cause the system to freeze up under any operating condition.

Fractional-horsepower motors for household and commercial refrigeration are manufactured with the stator windings unimpregnated because the varnish slows up the rate of dehydration. Oil also should be kept off the windings during the dehydration cycle. In case a unit is reworked, the oil all should be removed by washing in a solvent.

Once all motor materials, including insulation, have been established as suitable for a refrigeration system, no material changes should be made without first testing under actual operating conditions for a period sufficiently long to prove that the new materials are satisfactory for such use.

MECHANICAL DESIGN OF MOTOR PARTS

The motor industry through National Electrical Manufacturers Association (NEMA) has standardized on the stator outside diameter with tolerances, stator widths over the winding, and rotor bore with tolerances which permits the compressor manufacturer to establish standard dimensions and tolerance for the proper shaft fits in the rotor and the fit between the stator core and housings.

The motor laminations are made from the lowest core loss, highest permeability, and greatest thickness electrical sheet steel consistent with the high performance necessary, low cost, and good punchability of the steel. The refrigerator manufacturer is interested in both high efficiency and low costs. In most cases, the stator laminations are annealed to improve performance.

There must be sufficient rigidity in the stator construction to withstand ordinary handling without disturbing the close machining tolerances, thus facilitating assembly by the compressor manufacturer and promoting quality apparatus. Either welded or riveted stator cores or a frame wrapped around the stator core may be used, depending upon the features desired in the individual designs.

To date, the only practical insulation for the motor has been of the organic or AIEE Class *A* type. Paper is used for slot cells, barriers, slot wedges, separators, and connection and crossover wire insulators.

Cotton is used for sleeving over lead wires, and for binding the winding. The stator wire is usually covered with a polyvinyl acetal or other types of enamel. Sometimes the enamel has a cotton covering for the starting winding. Enamel wire in the main winding has resulted in more efficient designs compared with previous designs using double cotton covered wire. The stator windings may be put in by hand or, in many cases, the main winding at least is wound by machine which results in greater accuracy in the number of turns and lower cost.

As the windings in the stators for household refrigerator compressors are not impregnated with varnish, they will loosen at the end winding and also shift slightly in the slots. They are tied, but it is impossible with the type of insulation used to tie down the wires so that there is no relative motion in service after the paper and cotton are saturated with oil. Tightly wedging the wires in the slots minimizes any movement in the slots. The insulation must be so designed that no abrasion will result and cause short circuits or grounds. The motor manufacturer should maintain certain outline dimensions of the stator windings as consistent as possible with the nature of the winding.

In many cases, the completed stator is washed to cleanse it of foreign matter. The stator is then tested with equipment that detects short and open circuits in the main and starting winding and between each winding as well as detecting the wrong number of turns and grounds to the stator core.

The rotor is manufactured of the same grade of steel as the stator core and with either copper or die-cast aluminum cage. Aluminum free of magnesium and impurities is suitable for use in Freon-12 or sulphur dioxide, but not in methyl-chloride systems. The laminations are annealed before assembling into cores for die-cast rotors, and in many cases for copper-cage rotors. This eliminates the stray load losses, which cause dips in the speed-torque curve, and which reduce the pull-up and breakdown torques and efficiency. After the rotor is cast and the rotor surface and bore are finish machined, the complete rotor is then given a special heat treatment to reduce the stray load losses caused by die casting and machining operations. Many copper-cage rotors also get this treatment.

Test equipment has been devised to detect stray load losses, to check the speed-torque curve, to detect high resistance and broken bars, to indicate the wrong skew of the slots, and to show excessive eccentricity of the rotor. All of this equipment can be arranged to give a visual indication.

Some motor manufacturers give the motor a dynamometer test before shipping it to the compressor manufacturer. After test, the stator and rotor are wrapped in special cellophane bags to keep out moisture and foreign matter and then packed for shipment.

CLEANLINESS

One of the most important items necessary in manufacturing hermetically sealed units is cleanliness. The motor and compressor manufacturers have separate, as well as joint, responsibilities in maintaining cleanliness of the motor and compressor parts and the complete assembled unit.

The motor must be free of dirt, rust, paint, grinding dust, metal chips, and other insoluble matter as they will clog up small refrigerator passages, valves, and screens, as well as damaging the bearing surfaces and valves. No dirt should be permitted to collect between the laminations or in the winding as it may come out in service and get into the refrigerator system.

All materials in the motor and refrigerator system require extreme mechanical and chemical cleanliness, and a high degree of dehydration. For instance, all paper and cotton products must be free of waxes and other impurities which may be dissolved and deposited in the small passageways. They also must be free of lint, as it will clog screens in the refrigerant line. Wire enamels and such materials must be selected for freedom from the effects of oil and the refrigerant. This includes impregnating varnishes although they are seldom, if ever, used in household refrigerator motors. Core plate varnish or an excessive amount of oil on the motor laminations is not permissible.

There is also a joint responsibility in the selection of materials used in the motor and the balance of the refrigerator system so that no combination of the basic materials or their impurities will result in corrosion or products that will produce objectionable effects in the system.

It is the compressor manufacturer's responsibility to make certain that the compressor and other parts of the system are free of materials that will damage the motor. For instance, metal chips can readily short-circuit the winding. Cast iron and steel chips are easily attracted by the magnetic field and get into the winding. The compressor manufacturer should store the motor parts, prior to using them, in clean storage rooms of proper humidity to prevent rusting. He should handle them during assembly so as to avoid finger stains on steel parts, or rust will soon appear. He also should avoid getting dirt or oil in the winding because it may not be readily removed and may later get into the refrigerator system. He must handle the stators carefully so that the winding does not become damaged.

COMPRESSOR CONSTRUCTION

Common bearings are used for both the pump and motor and they are designed to provide adequate capacity for the combined load of the pump and motor. The crankshaft serves the pump and carries the rotor of the motor. An adequate lubrication system must be supplied and sufficient oil to last the life of the unit.

The stator is assembled into the housing with a press fit. This latter fit plays an important part in the transfer of the heat through the housings. The fit must be tight enough to hold the stator in place in the housing, even in vertical units, yet it must not be so tight that it will distort the stator.

Proper clearances must be maintained between the bearings and shaft. If clearances are too close, the shaft will freeze in the bearing under extreme temperature of load conditions. If too liberal, the shaft will rattle in the bearings. It is extremely important to maintain proper tolerances and surfaces in the bearings and on the shaft, otherwise the result will be more rejections in the factory and high service charges.

The unbalanced magnetic pull and noise from the motor increases rapidly with any uneveness of the air gap between the motor stator bore and rotor. This pull increases the pressure on the bearings and may break down the oil film. It also increases the stresses in the shaft. Therefore, the construction of the housing must be such as to permit accurate machining and assembly. An excess of oil in the air gap of the motor causes a drag on the rotor and requires more power input to maintain a given load.

The compressor manufacturer must provide adequate clearance between the stator winding extensions and the housing, recognizing the fact that the winding extensions cannot be formed to maintain as definite a shape as a solid section.

MOTOR FAILURES IN SERVICE

THE FOLLOWING motor failures may occur in service:

1. *Main winding* failures may be due to faulty wire; metal particles in the winding; nicks and abrasions on the winding and insulation caused by rough handling; inadequate test equipment; excessive burrs at ends of slots which may cut through the cells due to pressure and vibration; improper manufacture of the motor and compressor parts and assembly, including soldering of leads; failure of the thermostat and/or relay; excessive amount of water in the unit caused by improper dehydration or overheating; overheating motor insulation by improper control of the dehydration; abnormal voltages. The ultimate results are short circuits, open circuits, and grounds.
2. *Starting winding* failures may be due to the same reasons given for main winding failures. Many failures are due to thermostat failure or relay contacts welding, thus causing the current to flow for an excessive length of time in the starting winding. Repeated starts with insufficient time for equalization of the pressures may damage the winding. Failure of the starting winding by overheating also may damage the main winding.
3. *Die-cast rotor* failures caused by improper processing may be due to (1) excessive stray load losses resulting in a cusp in the speed-torque curve and difficulty in getting the load up to speed (this causes excessive time of the current in the starting windings, especially at low voltages), and (2) broken and/or high-resistance bars which affect performance.
4. *Sticking shafts* may be caused by (1) lack of lubrication for one cause or another, (2) breakdown of the oil caused by chemical reactions in the system, and (3) roughening of journals or bearings from corrosion.
5. *Noise.* The various types of noise caused by the motor may be due to excessive bearing clearances, poor finish of shaft and bearing, rotor not lined up properly with stator, broken and/or high-resistance bars in rotor, and poor motor design.

CONCLUSIONS

THE AUTHOR has attempted to emphasize the requirements and problems involved in applying motors to household refrigeration compressors. This also includes the associated electric equipment, the proper application of which is essential for a successful motor application. The success of the household refrigerator is evidence enough for the engineers and chemists responsible for the development and application of the motors, associated electric equipment, and compressors to feel proud of their achievement. The same fine co-operation that was responsible for the progress to date will continue to show progress in the future. We may look forward to even higher quality, longer life, and lower cost designs. Higher motor efficiencies may be expected.

It is very desirable to have insulating materials that would not be affected by heat or by the combination of refrigerant and oil, or by any chemical reaction resulting from the presence of moisture, to replace the present organic types of insulation. Many new materials have been made which look promising, but it takes two to three years to prove them in actual service and to develop them into practical and economical materials.

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Short-Circuit Ratings of Power Circuit Breakers

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THE SHORT-CIRCUIT RATINGS of power circuit breakers define the maximum short-circuit currents which the circuit breakers can be required to close, carry, and interrupt. These currents are transient and contain both direct and alternating components. They vary in magnitude between the time a fault occurs and the time the circuit breaker interrupts. Consequently, several ratings are used to define the maximum short-circuit current to which the circuit breaker may be subjected.

Standards specify how and for what time these values are measured, but American and European standards are not in complete agreement, particularly on interrupting ratings.

American interrupting ratings of power circuit breakers provide a rated interrupting current at rated voltage and a rated maximum interrupting current at reduced voltage. They are measured as the rms value of the total current at the instant of contact separation. A circuit breaker is required to interrupt these rated rms currents regardless of the relative magnitudes of the alternating and direct components.

European standards have two interrupting ratings, one for symmetrical currents and one, usually about 35 per cent higher, for asymmetrical currents. Both currents are measured at the same time and in practically the same manner as they are in the American Standards.

Various types of circuit breakers will be stressed differently by asymmetrical currents but the phenomena should be the same here as there.

Several factors determine the interrupting ability of a circuit breaker, with the result that when it is applied at various service voltages its limits may be either approximately the same rms current or the same kilovolt-amperes. For instance, many modern interrupting devices such as oil circuit breakers are most likely to interrupt at certain favorable positions during the opening stroke. Their arcing time is almost independent of voltage over relatively wide voltage ranges. If their interrupting ability is determined by mechanical strength or clogging of vent passages by arc products, the magnitude of the current is the important factor and they have a constant current limit.

If the ability of a circuit breaker to interrupt is determined by the initial recovery voltage, a reduction in transient recovery voltage produced by asymmetry of the current might cause a corresponding increase in its ability to interrupt current. Such a voltage-sensitive interrupter might have a 25- to 35-per-cent higher interrupting ability for asymmetrical currents, an increase which is roughly the same as the increase in rms current with constant alternating components and varying asymmetry.

These considerations indicate that standards which specify a single interrupting rating in rms amperes are satisfactory for current-sensitive circuit breakers, and that standards having symmetrical and asymmetrical ratings may be more satisfactory for voltage-sensitive circuit breakers which may have greater interrupting ability on asymmetrical currents.

If there are many circuit breakers in this country which are more voltage-sensitive than current-sensitive, an additional higher rating for asymmetrical currents only might be desirable. However, complications which would be produced by additional standard ratings probably would not be justified.

Circuit-breaker application can be simplified[1] by rating circuit breakers on the initial alternating component of the short-circuit current, a basic current value which must be calculated and from which the various rms values of the short-circuit current now are obtained for comparison with circuit-breaker ratings. The simplified ratings would be the initial alternating component of the short-circuit currents which the circuit breaker could close, carry, and interrupt at rated voltage; and for voltages below rating, the maximum initial alternating component of currents which can be closed, carried, and interrupted. Circuit breakers made to present standard ratings could be assigned the corresponding simplified ratings; most 8-cycle circuit breakers would be assigned initial alternating component ratings equal numerically to their present rated interrupting currents and the performance required of them would be unchanged.

To choose a circuit breaker, one would calculate as at present the symmetrical component of the initial current and would select a circuit breaker having an equal or greater rated initial current. The circuit breaker would be able to close that circuit even with fully asymmetrical faults and would be able to interrupt that circuit with any relay setting.

This simplified method[1] selects exactly the same circuit breaker and is applicable for the same conditions as the present recommended method.[2] The advantage gained is the reduction in the number of calculations and comparisons required in applying a circuit breaker.

More complicated applications, such as those involving large induction machines, large synchronous motors, or delayed tripping to keep the circuit breaker closed until the short circuit is within its interrupting rating, are made easily because in these cases too the number of application factors and operations is reduced.

Digest of paper 52-27, "Short-Circuit Ratings of Power Circuit Breakers," recommended by the AIEE Committee on Switchgear and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 21–25, 1952. Scheduled for publication in AIEE *Transactions*, volume 71, 1952.

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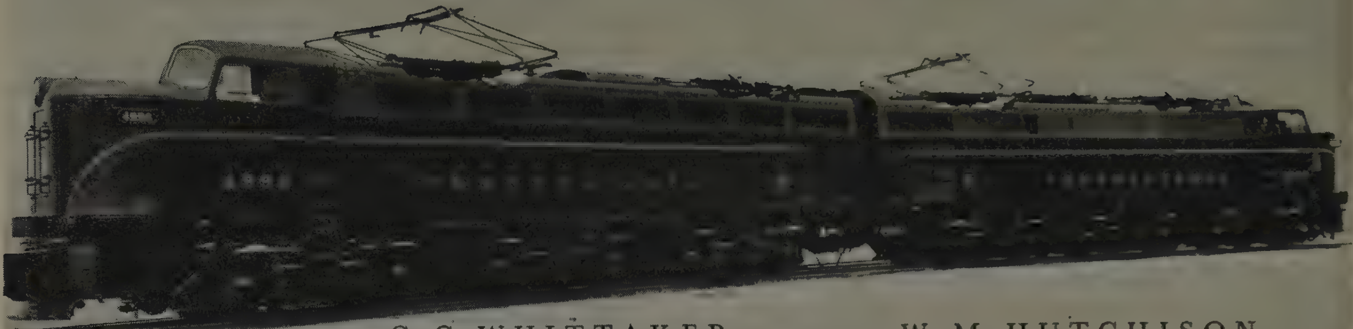
Pennsylvania Railroad Ignitron Rectifier Locomotive



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Extensive tests in the laboratory and on an experimental railway car have demonstrated that a locomotive using ignitron rectifiers offered promise in combining the best features of the a-c and d-c electrification systems. Two such locomotives have been built for the Pennsylvania Railroad; one, the 2 (B-B-B), is shown above.

THE TWO ignitron-rectifier electric freight locomotives of 6,000 horsepower recently placed in service by the Pennsylvania Railroad mark a significant innovation in the development of railroad motive power.

It has long been recognized that the low-voltage d-c series-wound motor is well suited for traction purposes. It has advantages over a-c traction motors of relative simplicity in construction and of the ability to develop higher starting torques without exceeding limitations on commutation or heating. On the other hand, the single-phase a-c system, as adopted by the Pennsylvania Railroad, results in economies in transmission and distribution systems, both in first and operating costs.

DEVELOPMENT OF IGNITRON MOTIVE POWER

THE DEVELOPMENT of the mercury-arc rectifier for converting alternating current into direct current offered an opportunity to combine the advantages of the two systems. As early as 1914, a mobile rectifier was applied to a 25-cycle 11,000-volt multiple-unit car operating on the New Haven Railroad. It was removed from service after 22,000 miles of operation because the rectifiers of that day had not been developed to the point where they were practical for such an application. They were of the multianode pumped type, and with the seals then available, difficulty was experienced in maintaining the vacuum. There were also frequent arc backs. With the advent of World War I, the idea was temporarily shelved.

In the 1920's, an alternate solution was developed in the form of the motor-generator locomotive. Such a locomotive converts high-voltage a-c power collected from the trolley to low-voltage direct current by a locomotive-mounted a-c transformer and synchronous-motor d-c generator set. A number of such locomotives have been built and have proved successful in the low-speed heavy-drag service for which they are particularly adapted; however, such locomotives are necessarily heavy and expensive.

It was the refinement of the ignitron type of rectifier in 1932, followed by its extensive application during World War II in the production of aluminum and magnesium, which turned attention again to the possibilities of a rectifier locomotive. Extensive tests were made to develop the soundness of the application, first in the laboratory and later in the field on a trial multiple-unit car. The problems and their solutions have been described in a previous paper.[1]

Those tests were so successful that in the spring of 1950 the Pennsylvania Railroad agreed to change an order for two a-c motored electric freight locomotives of a new type to ignitron-rectifier-equipped locomotives. These ignitron locomotives have several outstanding advantages:

1. They are applicable to the a-c trolley system with its high-voltage power supply.
2. They provide the same flexibility of control as the conventional a-c locomotive, a control unequalled for a wide range of sustained horsepower output.
3. They secure the high sustained tractive effort of d-c traction motors.

Essentially full text of paper **52-124** "The Pennsylvania Railroad Ignitron Rectifier Locomotive," recommended by the AIEE Committee on Land Transportation and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 21–25, 1952. Scheduled for publication in AIEE *Transactions*, volume 71, 1952.

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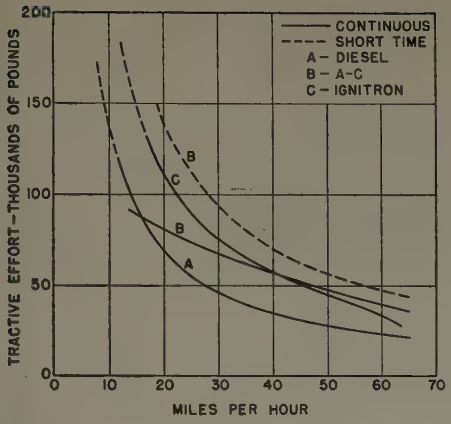

Figure 1. Locomotive performance curves

4. They incorporate apparatus which is currently produced in large quantity.

PERFORMANCE

Figure 1 illustrates the performance of ignitron locomotive in terms of tractive effort and speed in comparison with a standard 3-unit 4,500-horsepower (3,700 rail horsepower) diesel-electric locomotive in widespread use today, and a 2-unit 5,625-horsepower 25-cycle a-c locomotive. Each of these locomotives has 12 axles with a traction motor on each. The motors on the diesel locomotive are the same as those used on the ignitron locomotive. The a-c motors are the most modern of the resistance lead type. The mechanical features of the a-c motor locomotives are identical with the ignitron locomotives.

The curves of Figure 1 illustrate the fundamental differences in performance of three locomotive types and point up the advantages of the ignitron rectifier type. It will be noted that the rectifier locomotive develops about 60 per cent more tractive effort than the diesel-electric locomotive over the entire speed range. The a-c locomotive has an advantage over both the rectifier and diesel-electric locomotive in the high-speed range, as shown, but it will be noted also that in the low-speed range it is the weakest. The rectifier locomotive produces continuously almost 50 per cent more tractive effort in the low-speed zone.

The advantage of the a-c locomotive in producing a short-time overload far in excess of its continuous rating is indicated. Actually, it is also possible to design for an equivalent overload with the rectifier system. However, there is no need for the added capacity since the continuous rating gives adequate per-

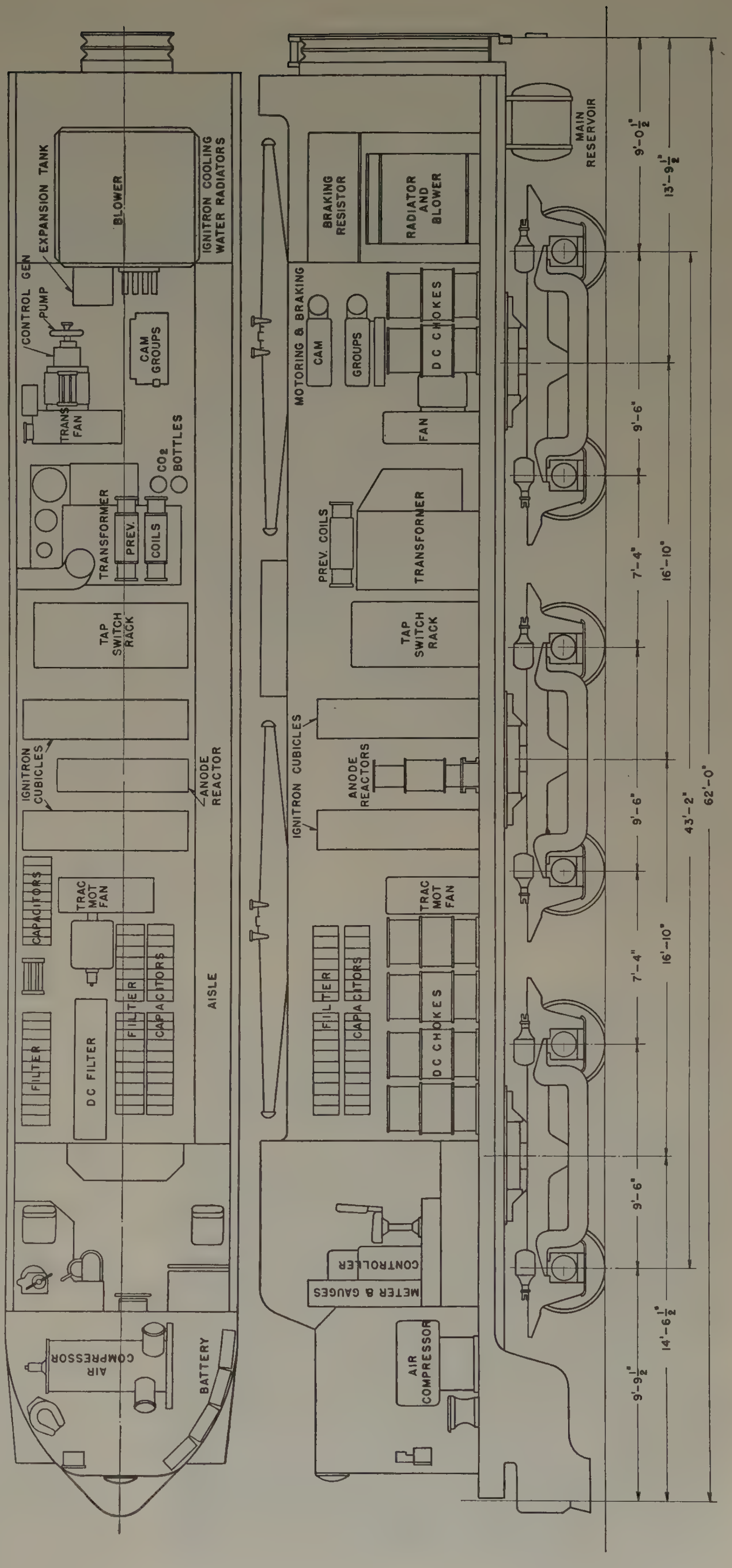

Figure 2. Cab layout of (A) unit, 3,000-horsepower 25-cycle rectifier locomotive

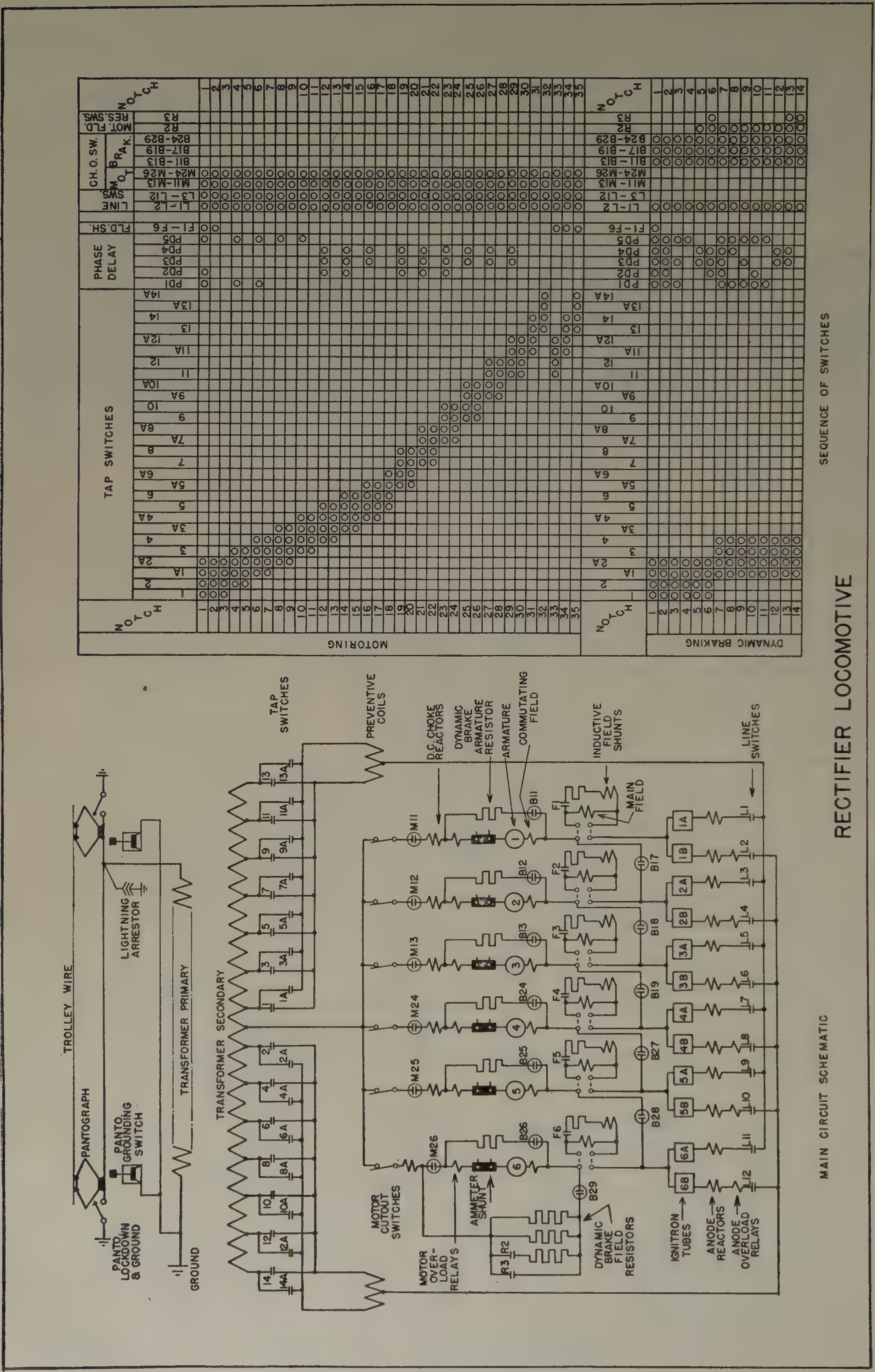

Figure 3. Main schematic diagram and switch sequence of a rectifier locomotive

Table I. Tonnage Ratings for a Typical Ruling Grade

12-Axle Locomotives

	Trailing Tons	Miles per Hour
Rectifier	4,600	40
A-c motor	4,700	
Diesel	2,700	
Rectifier	14,000	17
A-c motor	9,000	
Diesel	8,300	

Table II. Principal Data

Wheel arrangement	2(B-B-B)	2(C-C)
Line voltage, a-c	11,000	11,000
Phase	Single	Single
Frequency	25	25
Number of driving axles	12	12
Weight—total, pounds	751,000	728,000
Weight on drivers, pounds	751,000	728,000
Weight per driving axle, pounds	62,500	60,666
Continuous rating at rail		
Tractive effort, pounds	132,000	132,000
Speed—miles per hour	17	17
Adhesion—per cent	17.6	18.1
Starting tractive effort, pounds—25 per cent adhesion	187,750	182,000
Maximum operating speed, miles per hour	63	63
Number of traction motors	12	12
Driving wheel diameter	44 in.	44 in.
Gear ratio	15:68	15:68
Air-brake equipment	Type *8-EL* with *D-24* brake valve	
Number of compressors	2	2
Compressor air displacement—total cubic feet per minute	444	444
Type of control	Battery-electropneumatic	
Minimum curvature—coupled to train	16 deg	16 deg
Minimum curvature—locomotive only	21 deg	18 deg 30 ft
Length over-all—between knuckles	124 ft 0 in.	124 ft 0 in.
Total wheel base	104 ft 5 in.	104 ft 5 in.
Rigid wheel base	9 ft 6 in.	16 ft. 10 in.
Width over-all	10 ft 1½ in.	10 ft 1½ in.
Height over pantograph locked down	15 ft 0 in.	15 ft 0 in.
Height over cab	14 ft 7⅜ in.	14 ft 7⅜ in.
Width over cab	9 ft 10 in.	9 ft 10 in.
Track gauge	4 ft 8½ in.	4 ft 8½ in.
Coupler height	34 in.	34 in.
Clearance over rail—new wheels	5¼ in.	5¼ in.

formance in the low-speed range. The diesel-electric locomotive has a constant horsepower output, limited by the capacity of the diesel engine.

The information presented in these tractive effort curves can be translated into ability to pull trains. Table I shows tonnages that can be hauled by the three types of locomotives under comparison. These are based on a typical railroad division. The speeds shown occur on the ruling grade.

DIMENSIONS AND RATINGS

One of these locomotives is equipped with 2-axle trucks and the other with 3-axle trucks, the purpose being to determine by service tests which type of truck will be the more suitable.

The title photograph shows the 2(B-B-B) locomotive. The principal data and dimensions of the two locomotives having running gears 2(B-B-B) and 2(C-C) are shown in Table II. Figure 2 shows the cab layout of the principal pieces of apparatus. The single aisle was dictated by the size of the transformer and the length of the ignitron cubicles and tap-switch rack.

In these locomotives the ignitron rectifier and its associated apparatus are used to convert energy received from a 11,000-volt 25-cycle a-c trolley wire to direct current for the operation of the conventional d-c traction motors.

The ignitron rectifier is a mercury-arc device which employs an ignitor to initiate the arc at each positive half-cycle, and to permit the arc to cease at each negative half-cycle.

The transformer is inerteen-insulated and cooled by means of an air-blown radiator. Its design is essentially the same as that of a conventional a-c locomotive transformer except that the secondary is provided with a center tap with accelerating taps on both sides of the center. Because but one-half of the secondary is used for each half-cycle, the secondary winding is approximately 45 per cent larger than it would be for a single-phase series motor design. The inerteen is circulated by means of a pump built into the transformer tank. This transformer primary rates 4,200 kva at 11,000 volts. The tank is "form-fit" to minimize the volume of inerteen required.

CONTROL SCHEME—MOTORING

As will be seen from the main schematic diagram, Figure 3, the transformer secondary is provided with a mid-tap (d-c return) and a series of accelerating taps on each side of the mid-tap. These taps feed anode busses through preventive coils. Each anode bus feeds an ignitron tube through an anode circuit breaker and anode reactor. These two tubes supply full-wave rectified direct current to a single traction motor. From each individual motor, the circuit continues through a d-c choke reactor, which limits the ripple to approximately 30 per cent, a motor switch, and a cutout switch back to the mid-tap.

All six traction motors per (A) unit are similarly connected in parallel relation, in which connection slipping and spinning of drivers is minimized. In motoring there are 35 notches total. The sequence of switches is given with

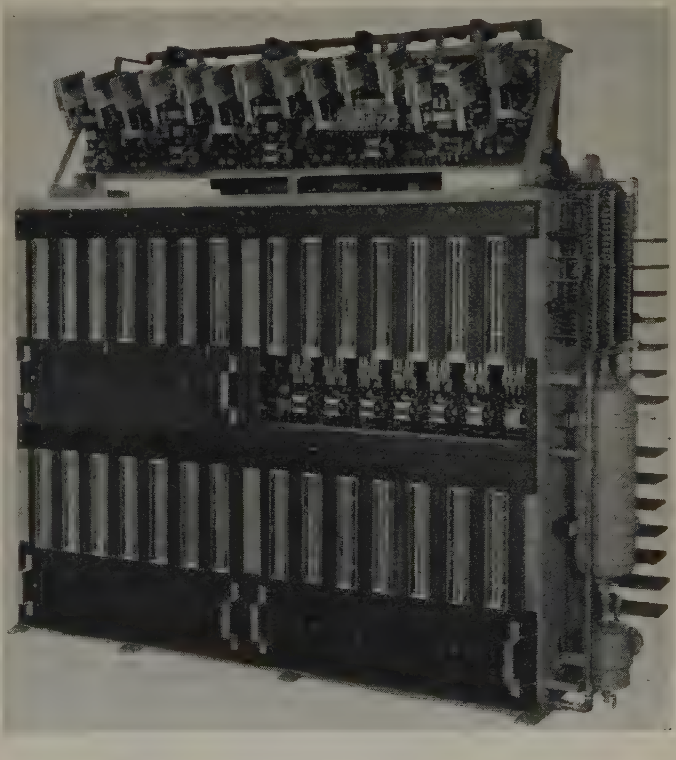

Figure 4. Front view of tap-switch rack

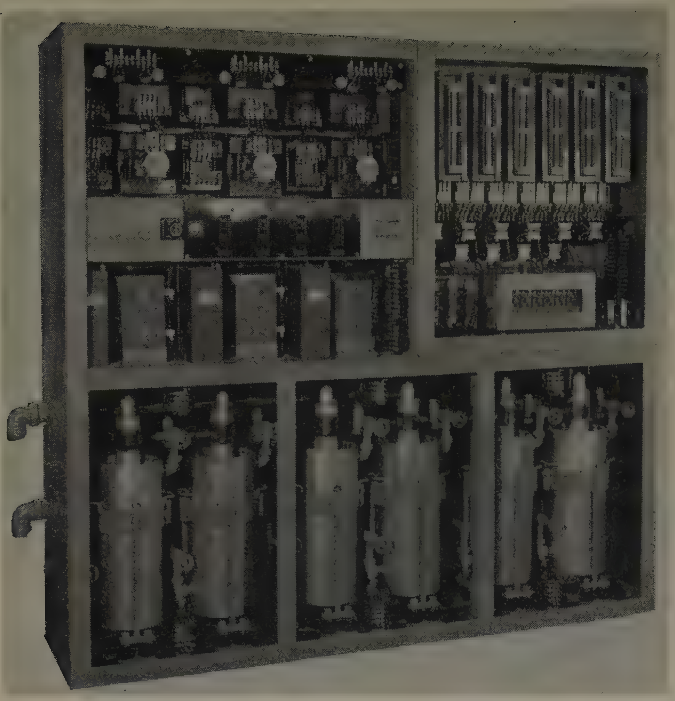

Figure 5. View of ignitron cubicle

the main schematic diagram. Phase delay of ignition to the tubes is used to increase the number of notches with a given number of transformer taps. This delay is varied up to 30 degrees in motoring and 50 degrees in braking.

Figure 4 is a front view of the tap-switch rack. This cubicle is entirely closed when in operation except for the arc-box openings. It is ventilated by approximately 3,000 cubic feet of air per minute, which is expelled through the arc boxes. The contactors on the top of the box are starting and running contactors for the auxiliary motors and include a heater contactor.

TRACTION MOTORS

The traction motors are type *370-DZ*, each rated 500 horsepower. These motors have six main and commutating poles. Both armature and field windings are silicone-insulated. Roller bearings are used on the armature shaft and sleeve bearings on the axles. These motors are the same as are used on Baldwin-Westinghouse and Fairbanks Morse diesel road locomotives.

AUXILIARIES AND VENTILATION

There are but three blower motors on each (A) unit. The traction motor blower ventilates the traction motors and supplies air for the windshield defrosters. It is a 1,450-rpm induction motor driving a number $4^1/_2$ B Buffalo Forge Niagara Conoidal runner requiring 43 horsepower.

Ventilation is by means of a duct in the underframe which feeds air into each 2-axle truck through the center pin and from the bolster to each motor. On the locomotive using the 3-axle trucks, air is fed to each motor by means of a sliding "high-hat" arrangement on the underside of the duct directly to the motors.

The transformer blower is driven by a motor-generator set. The motor of this set, which rates 29 horsepower, 1,450 rpm, also drives the control generator, a 45-volt 60-ampere machine and a centrifugal pump which circulates the cooling water for the ignitron tubes. This blower ventilates the transformer radiator, the tap switch group, the d-c chokes, and the motor reactors.

The radiators in the cooling system for the ignitron tubes are ventilated by an induction blower motor rated 35 horsepower, 1,450 rpm.

IGNITRON CUBICLES

Figure 5 shows a view of an ignitron cubicle. There are two cubicles per locomotive unit. Each ignitron tube is mounted by a resilient structure which holds the tube at approximately its center of gravity. The mounting structure itself is fastened to insulating bolts, thus leaving the cathodes insulated from ground. These tubes are standard except for some special mercury baffling. At the upper left are seen three firing circuit controls, and at the upper right there are six anode circuit breakers. Each circuit breaker must be capable of opening an arc back on an ignitron tube.

The most common trouble that has been associated with ignitron tubes in stationary service has been with arc backs. An arc back occurs when a cathode spot forms on the anode and a short circuit results. In a multiphase installation, the other phases feed power into this short circuit and the result may be a current flow of 50,000 amperes or more. It is also possible for a d-c load having stored energy in a shunt field to feed power back into the short circuit.

While using single phase for the railway application, no heavy arc backs have been experienced in several years of testing in our laboratories and two years' operation of the experimental multiple-unit car. If an arc back occurs, it is immediately extinguished at the next zero point on the voltage wave, and being a single-phase circuit, there is no other voltage present to reignite the arc independent of the ignitor itself.

Protective apparatus is provided to short-circuit the ignitor circuit and open the anode circuit breaker magnet-valve circuit when an overload occurs. This results in the overload current being interrupted within the ignitron tube because the overload trip operates in one-half cycle, and the anode circuit breaker takes $1^1/_2$ cycles to open. Therefore, after an overload operation, the anode circuit breaker opens without an arc. This anode circuit breaker shown in Figure 6 with arc box removed is a new design rated 1,200 amperes a-c or d-c. It makes use of die cast parts instead of sand castings. It has air-core blowout coils. These have proved especially effective on direct current because of no residual flux and on either alternating current or direct current have the feature of forcing the arc to the center of the arc box instead of burning arc box sides.

CONTROL SCHEME—BRAKING

When the dynamic brake feature is used, the traction motor fields are excited by using two ignitron tubes to provide direct current. These two tubes then feed all motor fields in series through a stepped resistor and then through one of the d-c chokes back to the mid-tap on the transformer.

Connected across each motor armature and commutating field is a braking resistor of fixed value. Fourteen notches in braking are obtained by the use of two taps on each side of the mid-point of the transformer secondary, by varying a series resistor, and by utilizing phase delay on the two ignitron tubes.

Figure 7 shows a single frame of the braking resistor. This resistor dissipates the energy supplied to it by one armature when braking. An overtemperature thermostat is provided in each braking circuit. Figure 8 shows one of the motoring-braking cam switch change-over groups.

The air brake is a combination of the *8-EL* type with a *DS-24* brake valve. The compressor is a Westinghouse Air Brake Company type *3-CD* driven by an induction motor. During the starting period, the compressor is unloaded and pumps against pressure only after it is up to speed. At 750 rpm, each compressor supplies 222 cubic feet per minute displacement.

CO_2 PROTECTION

Carbon dioxide protection against fire is provided by four 50-pound tanks of CO_2. The apparatus compartment in each (A) unit is provided with a 6-foot fire wall adjacent to the aisle to retain the gas when expelled around the electric equipment. Several discharge nozzles are located at strategic points. The blowers are shut down by the discharge of CO_2. While the transformer blower is slowing down, the reactors ventilated by this blower are filled with CO_2. The traction motor blower has its intake shut off completely when the CO_2 is discharged. Gas discharge may be initiated at either side of the locomotive inside the cab or at either side of the locomotive from ground level. In addition to these, there are portable CO_2 extinguishers.

At the time this article was written, the first of these two locomotives was undergoing tests preliminary to road acceptance tests by the railroad. These tests indicated that the locomotive had ample margin in both motoring and braking performance.

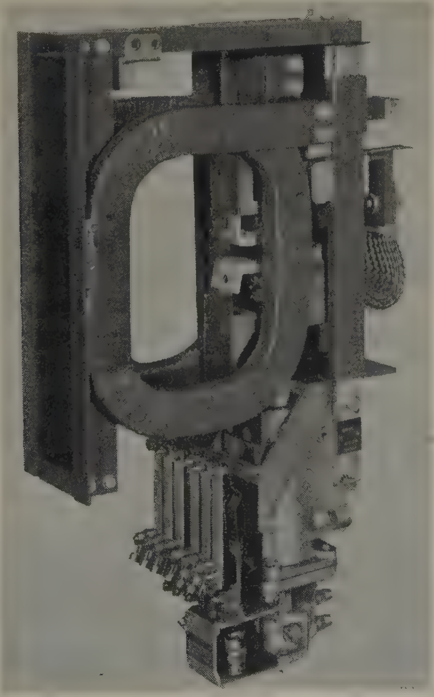

Figure 6. Anode circuit breaker with arc box removed

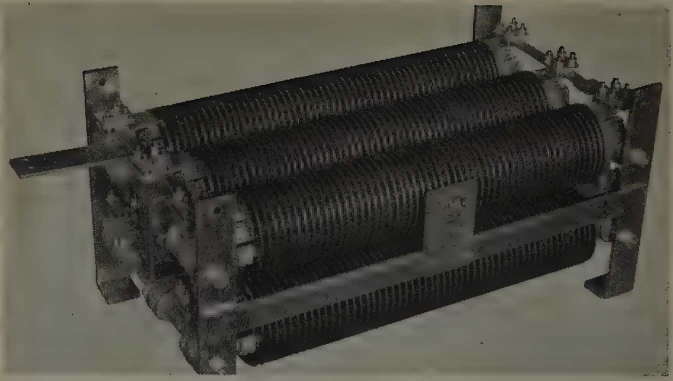

Figure 7. Dynamic brake resistor for one traction motor armature

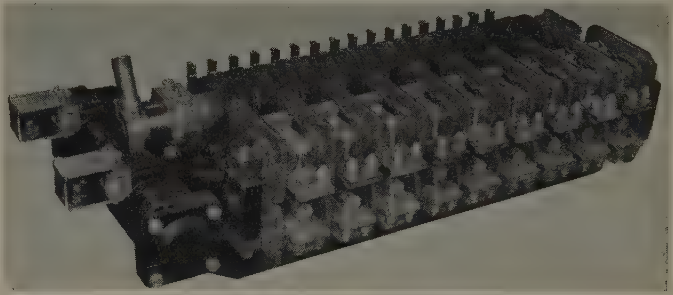

Figure 8. Cam switch change-over group for motoring and braking

In order to meet a satisfactory delivery date on these two ignitron locomotives and at the same time do some research work as to a-c and d-c filter requirements, it was thought best to build and equip the locomotives with the maximum size filters that it was thought might be required. Then, at a later date, after tests had been made in service, any excess filter capacity would be removed. This decision resulted in a somewhat crowded layout. Our tests to date indicate that we can remove the d-c filter and approximately one-half of the a-c filter. This will result in more accessibility and will remove approximately 11,000 pounds of capacitors and reactor.

CONCLUSION

Because these locomotives are just going into service, no operating results are yet available. Continued operation is expected to demonstrate the advantages of this type of locomotive on existing single-phase a-c systems.

Its application is not limited, however, to 25-cycle operation, but it is equally adaptable to frequencies of 50 or 60 cycles. The principal deterrent to railroad electrification in the United States is its high first cost. The ability of a rectifier locomotive to operate at commercial frequencies, as compared to a frequency of 25 cycles, necessitated by the limitations of a-c motor design, offers the possibility of reducing electrification costs and widening the field in which it is economically justified.

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Electromechanical Analogies of a Dynamo

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THE OBJECT OF electromechanical analogies is the establishment of a correspondence between a mechanical and an electric system. Where lumped elements can be used, the electric circuit analogue is attractive because of the well-developed electric circuit theory.

There are several forms of analogy; the direct or voltage-force analogy, the inverse or current-force analogy, and the frequency analogy in which the frequency of mechanical oscillations corresponds to a function of the frequency of oscillation of the electric system.

This article is concerned with electromechanical transducers utilizing electromagnetic forces and, in particular, with a separately excited d-c machine. The equations determining the acceleration of the rotor are

$$E_r = R_r I_r + L_r \frac{dI_r}{dt} + M_d I_s \omega_r \qquad (1)$$

$$T_r = -M_d I_s I_r + K_r \omega_r + M_r \frac{d\omega_r}{dt} \qquad (2)$$

where E denotes voltage, T torque, I current, ω angular velocity, R electric resistance, K viscous damping, L inductance, and M_r inertia. The subscript s denotes stator and r the rotor. M_d is the mutual inductance of the stator and rotor circuits when the stator and brush axes are coincident.

Assuming that the stator current is constant, the terms in equations 1 and 2 may be replaced by their Laplace transforms and written in matrix form as

$$\begin{bmatrix} E_r \\ T_r \end{bmatrix} = \begin{bmatrix} R_r + L_r p & M_d I_s \\ -M_d I_s & K_r + M_r p \end{bmatrix} \begin{bmatrix} I_r \\ \omega_r \end{bmatrix} - \begin{bmatrix} L_r I_{r0} \\ M_r \omega_{r0} \end{bmatrix} \qquad (3)$$

where $I_r = I_{r0}$ at $t=0$, and $\omega_r = \omega_{r0}$ at $t=0$.

It will be noted that the impedance matrix in equation 3 is asymmetrical, and therefore cannot be represented by an equivalent electric circuit. However, by using the inverse analogy, that is, representing torque by current and angular velocity by voltage, the impedance becomes symmetrical and consequently can be represented by an equivalent circuit. Thus, rules can be established for the construction of the electric analogue without recourse to the performance equations of the system. The equivalent electric circuit may be drawn directly from the electromechanical system to be analyzed. Initial conditions are introduced readily; for example, initial compression or tension of a spring becomes an initial current in an inductance. In some cases it may be expedient to use the dual of the previous analogues. Nonlinear effects can be introduced into electric circuits, and permit study of nonlinear problems which are tedious to solve by computation.

Thus it may be shown that the electric analogue of a separately excited d-c machine with constant excitation, the rotor flexibly connected to a load, and the stator flexibly connected to a foundation is as developed in Figure 1. This circuit may be of value in the study of vibration problems as it permits motion of the stator as well as the rotor.

The mechanical constants used in the analogy may be determined by electrical or mechanical tests. The constants of a 220-volt 2,300-rpm 6.5-ampere separately excited d-c machine were measured. Then the rotor of the machine was connected through a flexible torsion spring to a rigid foundation, the stator being fixed. The current response to a step function input of a magnitude of 25 volts was measured. The response as calculated from the measured system constants is in good agreement with the observed response.

If the field current is variable the equations become nonlinear, but it is possible to reduce them to a linear form by considering small oscillations. By the use of feedback from the output shaft, it should be possible to change the time of response and the general characteristics of the machine.

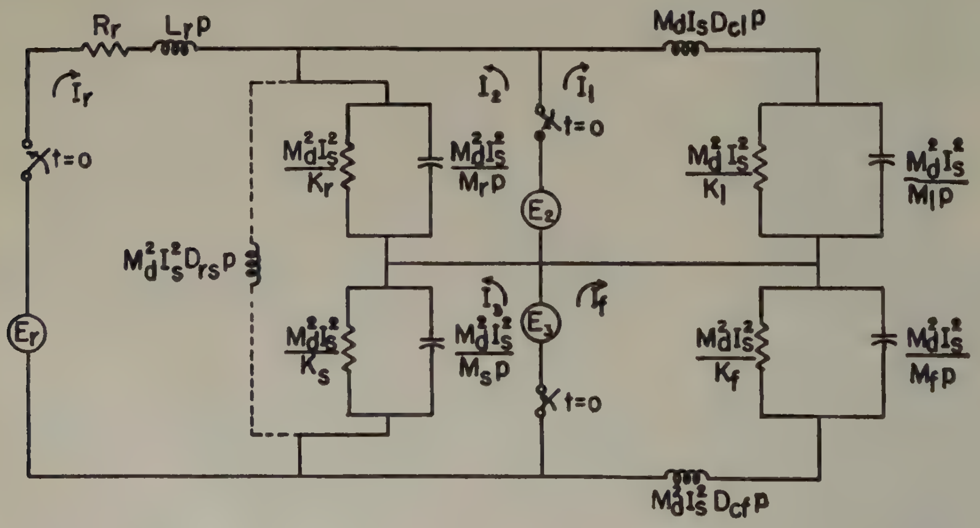
R_r
$L_r p$
$M_d I_s D_{cl} p$
I_r
I_2
I_1
t=0
t=0
$\frac{M_d^2 I_s^2}{K_r}$
$\frac{M_d^2 I_s^2}{M_r p}$
E_2
$\frac{M_d^2 I_s^2}{K_l}$
$\frac{M_d^2 I_s^2}{M_l p}$
$M_d^2 I_s^2 D_{rs} p$
E_r
I_3
E_3
I_f
$\frac{M_d^2 I_s^2}{K_s}$
$\frac{M_d^2 I_s^2}{M_s p}$
t=0
$\frac{M_d^2 I_s^2}{K_f}$
$\frac{M_d^2 I_s^2}{M_f p}$
$M_d^2 I_s^2 D_{cf} p$

Figure 1. Equivalent circuit of a separately excited d-c machine with rotor and stator free to rotate and with a flexibly connected load on the rotor and a foundation on the stator. s denotes stator, r rotor, c coupling, l load, and f foundation

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Digest of paper 52-45, "Electromechanical Analogies of a Separately Excited D-C Machine," recommended by the AIEE Committee on Basic Sciences and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 21–25, 1952. Scheduled for publication in AIEE *Transactions*, volume 71, 1952.

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A Power System Analogue and Network Computer

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THE NETWORK ANALYZER has become a practical necessity in the solution of complex power-system problems. Since a few weeks a year on rented calculators have proved inadequate, The Detroit Edison Company has designed and installed a system analogue and network computer to provide full-time use of this essential engineering tool. Inasmuch as this device would be used for the study of current operating problems aimed at obtaining optimum system performance, as well as for system-planning functions, it seemed desirable to combine a conventional, completely variable network calculator with a fixed permanently connected section which is a factual reproduction of the company's bulk power system.

The design of the system analogue provides facilities for duplicating readily all the functions of normal operation in the actual system. The identification of analogue elements by the specific names and numbers used for the system counterparts, and the permanent arrangement of stations, busses, and equipment in a pattern familiar to the system operators, result in a minimum of confusion in translating system operation into analogue operation.

The network computer is similar, functionally, to other network analyzers, and provides for the study of problems involving the expansion of the present bulk power system, the distribution system, or, in general, any power system.

The analogue and computer can be used separately or combined as one unit, and a single metering-recording console serves both sections. A partial view of the unit is shown in Figure 1. To the left of the center column are the ten frames of the analogue and to the right are shown six of the ten frames of the computer. The console for metering and recording is in the center foreground. Also shown is the special panel lighting in the ceiling, designed to give uniform, nonglare lighting on the vertical panels and at the console. Table I gives the number of elements of each type available.

The unique features of this analogue computer, compared with most other network analyzers, are: 1. the combination of the analogue of a particular system with a generalized network analyzer; 2. the use of 60 cycles, instead of the higher frequencies more commonly used; 3. the use of the transformer type of board generators, instead of the movable-rotor type; 4. the calibrating of capacitors and loads directly in per cent of load instead of in impedance; 5. provision for reading voltage both in per cent or in meter volts, that is, the voltage actually read on the system meters; and 6. treatment of units representing synchronous condensers like load units, so that output can be maintained constantly even with changes of bus voltage.

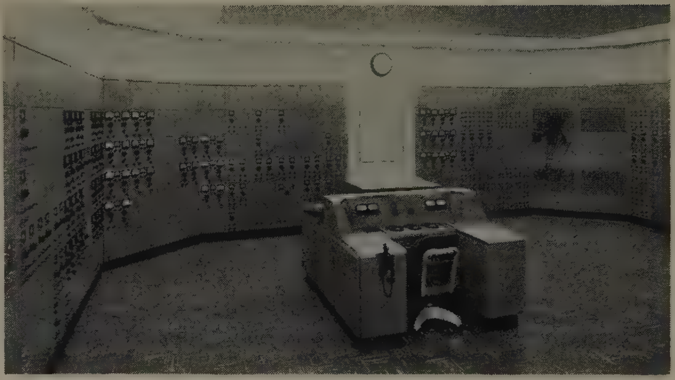

Figure 1. A partial view of the system analogue and network computer

Table I. Classification of Units in the System Analogue and Network Computer

Unit	Analogue	Computer	Total A*	Total B**
Generators	27	6	33	33
Loads	33	40	73	73
Transformer taps	44	16	60	60
Impedances	64	48	112	48
Pi circuits	59	48	107	48
Synchronous condensers	3	6	9	9
Capacitors	7	16	23	16
Mutual transformers	0	8	8	8

* Detroit Edison System ** Other Systems

In making the decision to procure a network calculator for the exclusive use of this one company, the major factor was the increasing need for greater use and more immediate availability of such a tool for the solution of engineering planning problems. With the greater precision thus obtainable, savings in construction costs should result because the construction can be matched more closely to the actual needs.

The decision for this particular type of analyzer was based largely on the hope that the design features incorporated would make it a more valuable aid in obtaining optimum system operation. There was also the desire to provide facilities for training young engineers and operators in the more effectual solution of engineering and operating problems.

Since the equipment has been in service only a short time it is too early to state definitely whether some of the departures from more conventional design will prove distinctly advantageous. Results to date, however, have been encouraging. The setup and calibration procedure is direct and fast, the balancing operation is exceptionally smooth and stable, the metering and recording procedures are on a par with other modern calculators, and the overall accuracy seems to be well within the requirements.

Digest of paper 52-62, "A Power System Analogue and Network Computer," recommended by the AIEE Committee on System Engineering and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 21–25, 1952. Scheduled for publication in AIEE *Transactions*, volume 71, 1952.

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A High-Speed Recording Oscillograph

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The Oscilloscribe is a high-speed oscillograph which makes ink records on a fast-moving chart of voltages having frequency components ranging from direct current to 200 cycles per second. The basic element of the instrument, which is actually a servomechanism, is a D'Arsonval meter movement with no restoring springs.

THE OSCILLOSCRIBE* is a very-high-speed direct-writing oscillograph which produces an immediate permanent record of voltages having frequency components ranging from direct current to 200 cycles per second. Development of this device was started in February 1947, when comparable devices were not available commercially. Since that time several instruments of this general type have appeared on the market and have found a wide variety of applications.[1]

The Oscilloscribe, however, is markedly superior to previously reported devices in several important respects. This superiority is made possible by the application of position feedback to the problem of the high-speed recording voltmeter.** The Oscilloscribe is actually a high performance servomechanism whose block diagram is shown in Figure 1.

The basic element of the instrument shown in Figure 2 is a D'Arsonval type of meter movement having no restoring springs. A 3-inch pen is attached to one end of the movement and a single-plate capacitor rotor is attached to the other end. The position of the capacitor rotor is translated into a direct voltage by means of a radio-frequency (r-f) capacity bridge and a detector. The detector output is compared with the applied signal and their difference is amplified and applied to the moving coil. The coil moves until this difference becomes zero. The pen is then held in this position on a paper chart and is caused to draw a continuous line by running the chart at a constant speed. Figure 3 shows the complete instrument.

Extensive requirements were placed on the system at the start of the project and the meeting of these requirements led to many interesting design problems. In order that the nature of these problems may be fully appreciated, the system requirements are listed here:

Record instantaneously and permanently voltages of a steady or varying nature.
Instrument must be portable.
Power requirements—110 volts, 60 cycles only.
Frequency response—flat within 3 decibels from direct current to 200 cycles per second.
Maximum sensitivity—one millivolt per millimeter.
Maximum drift—two per cent of full scale after warm up.
Full scale deflection—±2.5 centimeters at a 3-inch radius.
Linearity—within one per cent over whole range.
Calibration—adjustable in steps from 25 millivolts to 250 volts full scale.
Zero position—adjustable to any point on scale.
Input impedance—one megohm on all ranges.
Chart drive—three constant speeds.

Any servomechanism is comprised of component functional units, each of which must be designed by keeping in mind the ultimate performance of the entire system. In a high performance servo of the type being described here, certain units become very crucial and must be designed in accordance with very close tolerances while others, requiring less stringent tolerances, can be designed with an eye to minimizing size and cost. These units now will be described, along with certain considerations which affected their design.

THE PEN AND PEN MOTOR

THE MAGNETIC CIRCUIT of the pen motor consists of a permanent magnet with cylindrical pole faces which are separated from a cylindrical iron core by a 1/8-inch air gap. The moving element consists of a 500-turn coil of number 40 copper wire wound on a nonconducting rectangular frame which is rigidly attached to a 1/16-inch steel shaft. The shaft passes through the hollow center of the stationary iron core and is supported by ball bearings mounted at the top and bottom of the core.

Current is supplied to the coil through two flexible beryllium copper wires. When current passes through the vertical portions of the coil which are situated in the radially directed magnetic field of the cylindrical air gap, a torque is developed which is proportional to the current. The coil is then free to rotate until it encounters sponge rubber stops at ±20 degrees. A high resistance is connected in series with the coil during the brief warm-up period to prevent damaging currents which can result from temporary amplifier unbalance.

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* This instrument was developed in the Servomechanisms Laboratory of the Department of Electrical Engineering, Yale University, New Haven, Conn.

** Position feedback had been applied previously in recording voltmeters but the fastest of these could not respond beyond 15 cycles per second.

Revised text of paper 52-54, "A High-Speed Direct-Writing Oscillograph," recommended by the AIEE Committee on Instruments and Measurements and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 21–25, 1952. Scheduled for publication in AIEE *Transactions*, volume 71, 1952.

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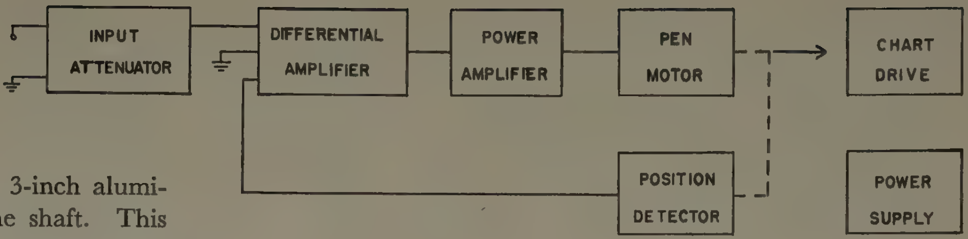
Figure 1. Functional block diagram of the Oscilloscribe



The actual writing is done by a 3-inch aluminum pen attached to the top of the shaft. This pen is a modified version of a lightweight commercial model which ordinarily depends on capillary attraction to draw ink from the well. Since this pen was designed to work at writing speeds up to only 100 cycles per second, two modifications were needed. It was found necessary to stiffen the pen considerably in the lateral direction since it resonated like a vibrating reed at about 120 cycles per second. A triangular shaped aluminum truss structure accomplished the desired result at the expense of an increase in moment of inertia. At the same time, this truss provided the type of aerodynamic surface necessary to keep the pen down on the chart whenever the pen is oscillating at very high speeds. In addition, the opening at the pen's tip was enlarged and the inkwell was mounted above the plane of the pen to permit a flow of ink sufficient to draw a clear line on the chart even when the pen is oscillating at very high speeds.

Situated at the bottom end of the shaft is a thin aluminum capacitor rotor having a half-inch radius and a 70-degree sectoral angle. This rotor moves in the horizontal plane between two split stator plates. The detector circuit is so designed that the rotor operates at ground potential and thus requires no special insulation from the shaft. To insure that a reliable r-f ground connection always exists, a flexible beryllium-copper lead-wire is used as a direct ground for the rotor.

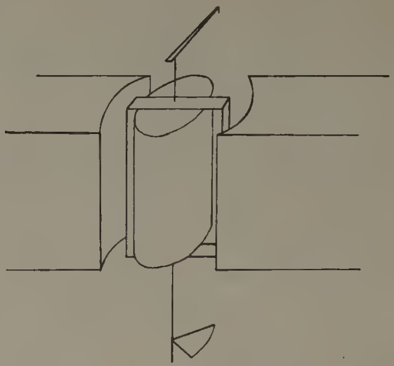
The pen and pen motor are obviously very important elements of the system. However, because of the use of position feedback, their precise behavior in this system is much less critical than in comparable spring-restrained devices.

THE POSITION DETECTOR

THE POSITION DETECTOR is a very critical part of the entire system so far as accuracy is concerned since it must convert the position of the pen into a voltage suitable for comparison with the input voltage. Furthermore, this conversion must be done linearly, with reversible polarity, without appreciable time delay, and without introducing spurious signals. These spurious signals might arise from electrical sources such as drift and hum or they might arise from mechanical imperfections which cause motions of the pen-motor shaft other than pure rotation. A variable capacitor operating with an r-f signal applied was chosen as the transducer because of its small size. Furthermore, when used in a split-stator bridge circuit it can result in a detector which is insensitive to vertical or radial motions of the shaft.

The variable capacitor and the demodulating circuits are shown in Figure 4. A 4.3-megacycle signal is generated by a crystal oscillator and amplified by a resistance-capacitance-coupled triode and a pentode limiter. The pentode supplies an essentially constant current to the tuned primary of the r-f transformer which has an electrostatically shielded secondary. The shielded construction insures that voltages appearing in the secondary arise from

Figure 2. The pen, pen motor, and capacitor rotor of the Oscilloscribe position detector



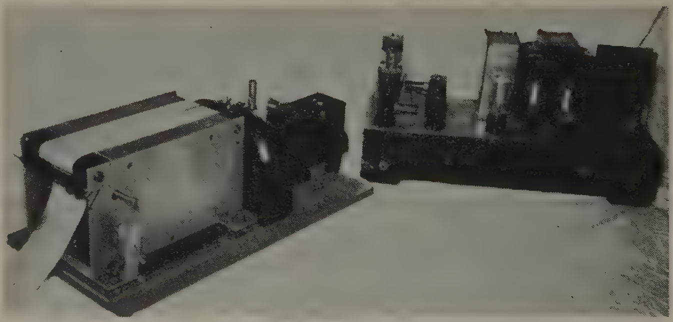


Figure 3. The experimental model of the Oscilloscribe in its final form

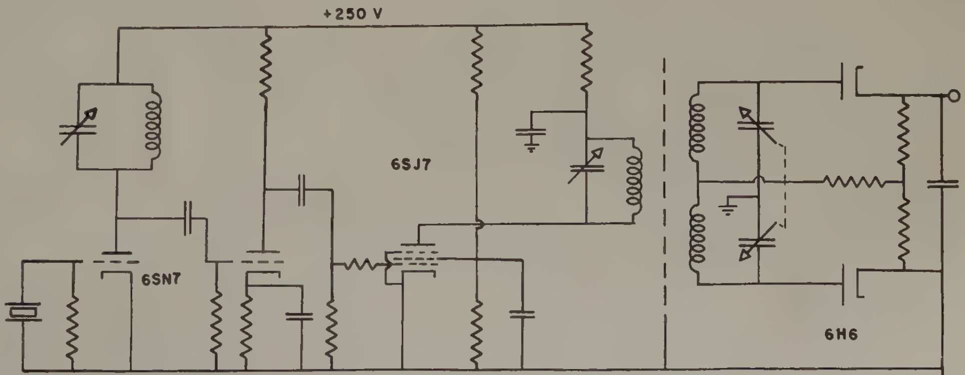


Figure 4. Schematic diagram of the position detector showing the location of the split-plate capacitor (dashed line)

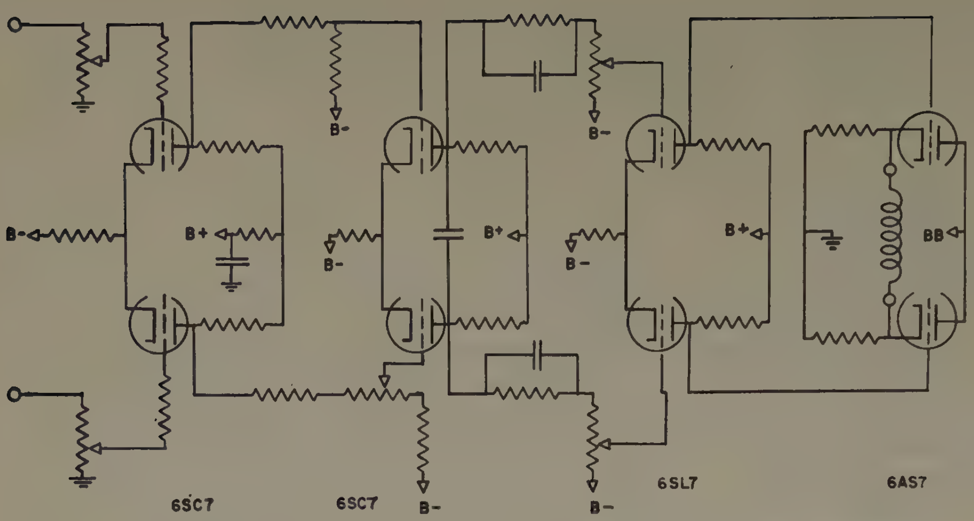


Figure 5. Schematic diagram of the differential amplifier and the power amplifier

induction only. Furthermore, the shield insures a reasonably even distribution of capacity from the secondary to ground so that the apparent ground appears at the midpoint of the secondary.

By grounding the rotor of the transducer and connecting the stators to the ends of the secondary, the apparent ground can be made to shift with the position of the rotor. A high-impedance diode circuit connected between one end of the transformer and ground will develop a direct voltage which depends upon the position of the apparent ground on the transformer secondary. Two such diode circuits connected as shown permit the output to reverse polarity when the rotor swings from positive to negative angles.

A 2-megohm resistor serves to provide a return path for the direct currents of both rectifiers without affecting the position of the apparent ground. A careful analysis based upon the assumptions that the distributed capacities far exceed the maximum capacity of the rotating capacitor and that the frequency is sufficiently high so that the reactance of the total capacity to ground from each end of the secondary is very much smaller than the effective diode circuit-impedance, shows that the output voltage is directly proportional to the angular position of the rotor. Furthermore, under these conditions it can be shown that the detector is essentially insensitive to vertical or radial motions of the shaft.

THE DIFFERENTIAL AMPLIFIER

THE DIFFERENTIAL AMPLIFIER and the power amplifier shown in Figure 5 have numerous advantageous features. When properly designed, the balanced type of amplifier used in the first three stages produces an output voltage between the plates of the tubes which is strictly proportional to the difference in the voltages applied to the grids of the tubes. Thus, the difference in the plate voltages of the first stage is proportional to the difference between the input voltage and the position feedback voltage.

Since the plate voltages of the first stage are both quiescent at a very high direct potential, their difference cannot be amplified directly by a single triode. This requires that the second stage also be a subtractor, with the plate voltages of the first stage applied to each of its grids. The third stage also operates in this fashion and supplies its output voltage directly to the grids of the balanced power amplifier.

It is evident that if the tubes are perfectly matched in this type of design, noise in the power supplies, hum from the filaments, or changes of supply voltages will introduce none of the spurious signals which can occur in single ended designs.[2,3] Even when the two halves of each subtractor are not perfectly matched, discrimination against common mode signals is very good. Tests made on a *6SC7* twin triode with common cathodes showed that a 10-volt change in B+ voltage causes a 0.4-volt output signal. Referred to the input, this is equivalent to a spurious signal of 0.01 volt. Since the sensitive amplifiers are connected to power supplies and filament supplies which are themselves well regulated and filtered, it can be seen that the combination is a simple yet effective method of guarding against drift and noise trouble which can arise in high-gain d-c amplifiers.

Provision for quiescently balancing the amplifier or setting the pen to any desired zero position is made by including a potentiometer in one of the coupling networks between the first and second stages. In this position the zeroing arrangement places no special requirements on the regulation of the power supplies.

Attenuation is deliberately introduced between the second and third stages so that phase lead equalizers may be incorporated into the system by simply adding a capacitor on each side of the amplifier. The shunt resistors at this point are potentiometers which are ganged together. This provides a means of adjusting the gain of the amplifier without upsetting the bias arrangements since the cathode of the third stage will follow common changes in its quiescent grid voltages.

The 1-megohm input attenuator is designed in steps of 10/1 and 4/1. The attenuator switch has a sliding contactor which prevents the grid circuit from opening during the switching process. A 200,000-ohm resistor is inserted in each grid lead so that the grid circuit resistances will be approximately equal on all ranges. This eliminates shifting of the zero between ranges by equalizing the voltages caused by grid current flow in each triode.

The first stage which amplifies signals in the 10-millivolt range is operated at a reduced plate potential to permit the use of a larger cathode resistor, thus making the circuit a more nearly perfect subtractor even when the two halves of the tube are not perfectly matched. At the same time, an opportunity is afforded for additional filtering of plate supply to the very sensitive first stage.

THE POWER AMPLIFIER

THE POWER AMPLIFIER's function is to drive current through the moving coil proportional to the amplified error voltage. This current must be sufficient to develop the peak values of torque required to oscillate the moving system sinusoidally with a prescribed amplitude, particularly at the high end of the frequency range.

The power amplifier which is employed for this purpose is peculiarly suited to the requirements of this instrument. As shown in Figure 5, it is a balanced cathode follower which is capable of supplying a large reversible current to a 2-terminal coil without requiring a B-supply. This circuit has the particularly advantageous features of requiring no high current negative voltage supply, no center tap on the moving coil, no special filtering or regulation on the B+ supply, and under quiescent operation produces no heating in the moving coil since the quiescent-coil current is zero. Furthermore, the effective source resistance of this circuit, which has an important influence on the effective time constant of the moving system, is as low as usually can be obtained in single-tube circuits. When the *6AS7* twin triode is used in this circuit it can supply ±90 milliamperes linearly to the coil when a potential difference of ±60 volts is applied to the grids. This circuit has a source resistance of 200 ohms and a gain factor of 0.6.

THE POWER SUPPLY

AS WILL BE DISCUSSED in later paragraphs, the ability of the system to write with appreciable amplitude is governed by the maximum current available for accelerating the moving system. Since the entire unit was to be portable, a 225-milliampere supply was chosen as the largest practical size. Its circuit is shown in Figure 6.

The power amplifier required 200 milliamperes at 250 volts which, because of the balanced design and the over-all position feedback, did not have to be perfectly filtered or regulated. The output of the capacitor input filter is 385 volts unregulated with a 1.3-volt rms ripple.

The d-c amplifier required +250-volt and −150-volt regulated supplies while the detector also required +250 volts. The total current required was approximately 20 milliamperes. The critical first stage of the amplifier placed the most stringent requirements on the power supply design since any noise or drift originating in the first stage would be indistinguishable from the applied signals. However, because of the balanced design of the amplifiers, voltage-regulator tube regulation with an additional stage of resistance-capacitive filtering proved adequate for the system. The ripple voltages, when finally measured, were 0.017 volt rms on the +250-volt supply, and were 0.022 volt rms on the −150-volt supply.

In addition to the foregoing precautions against the introduction of drift signals, a further step was taken against the situation which might arise when changes of filament voltage could introduce different contact potentials in each half of the critical first stage if its two halves were not perfectly matched. The use of a constant-current ballast tube in the filament supply thus eliminates the need for selecting carefully matched twin triodes for the first stage.

A balancing potentiometer connected across the filaments of the first stage reduced the 60-cycle hum level to the point where it causes no observable effect on the written track.

THE CHART DRIVE

THE CHART DRIVE consists of a 75-rpm single-phase motor which drives the chart through a gear box. The gear ratios may be changed by manual adjustment to permit chart speeds of 35, 100, and 200 millimeters per second. The motor pulls the chart along the chart table while the feed roll is friction-restrained so that the chart remains taut. The weight of the paper falling freely provides a satisfactory take-up system for the paper coming out of the chart drive.

The 200-millimeter-per-second maximum speed permits each cycle of a 200-cycle-per-second signal to be traced out in a 1-millimeter interval.

DYNAMIC PERFORMANCE REQUIREMENTS AND OVER-ALL SYSTEM DESIGN

THE MAJOR OBJECTIVES in the over-all system design were twofold:

1. The frequency response should be essentially flat from direct current to as high a frequency as possible.
2. At the high end of this frequency range the system must be able to deflect with an appreciable amplitude.

It is apparent that, although item 1 may be the prime objective of the entire design, its realization will be of little

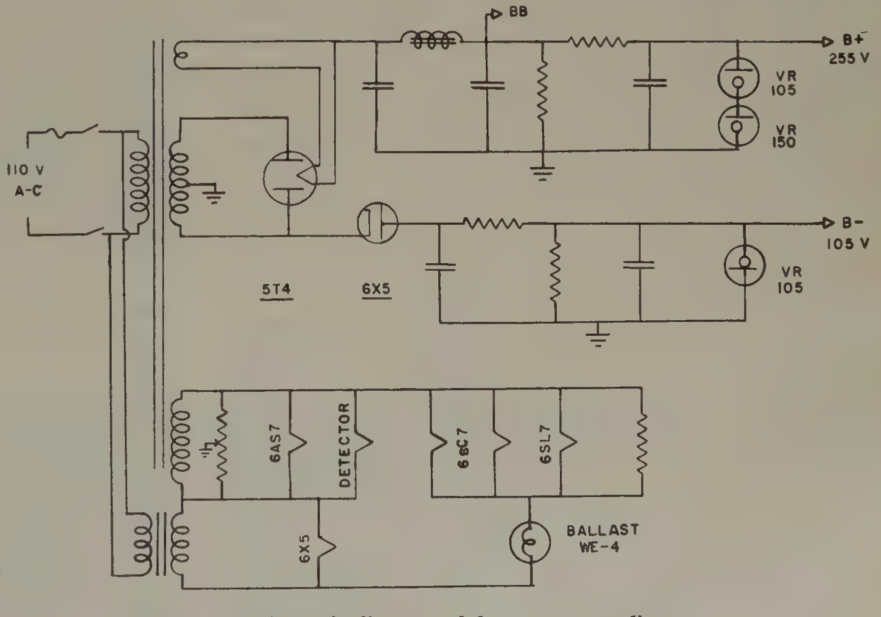


Figure 6. Schematic diagram of the power supplies

consequence if objective 2 is not realized simultaneously. Actually, it happens that objective 2 imposes the more fundamental requirements on the various functional elements of the system. Therefore, it must be given first consideration here.

The exact nature of the requirements imposed by objective 2 is revealed by the following equation

$$i=\frac{J}{K_t}\,S^2\Theta$$

where i is the coil current; J, the moment of inertia of the moving system; K_t, torque developed per unit of coil current; S, the derivative operator; and Θ, the coil position.

From this equation it follows that if the pen is to deflect linearly with a maximum amplitude Θ_m in response to a sinusoidal input of maximum angular frequency ω_m, then the peak current required by the moving coil is given by:

$$I_m=\frac{J}{K_t}\,\omega_m^2\Theta_m$$

This result suggests that the power supply and the power amplifier be made as large as possible to supply this current. However, size and weight considerations fix the maximum current capacity for the power supply and the corresponding power amplifier. It then becomes a matter of designing the moving system in accord with the following considerations:

(*a*). All of the available current capacity should be usable in a linear manner without encountering voltage limitations.
(*b*). The coil must be capable of carrying the maximum available current without damage to itself.
(*c*). The inertia/torque-constant ratio (J/K_t) should be minimized.

One procedure clearly indicated is to increase the magnetic flux density in the air gap, thus increasing K_t directly. However, saturation effects and physical size limitations set an upper limit for this effort (approximately 6,500 lines per square inch in the final design).

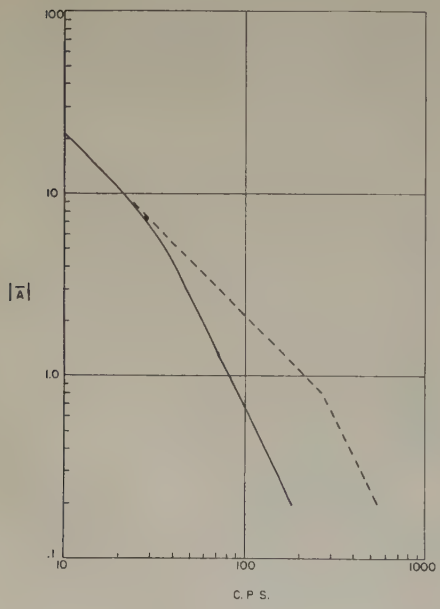


Figure 7. Magnitude of the open-loop transmission ratio versus frequency; solid curve is before equalization and dotted curve after equalization

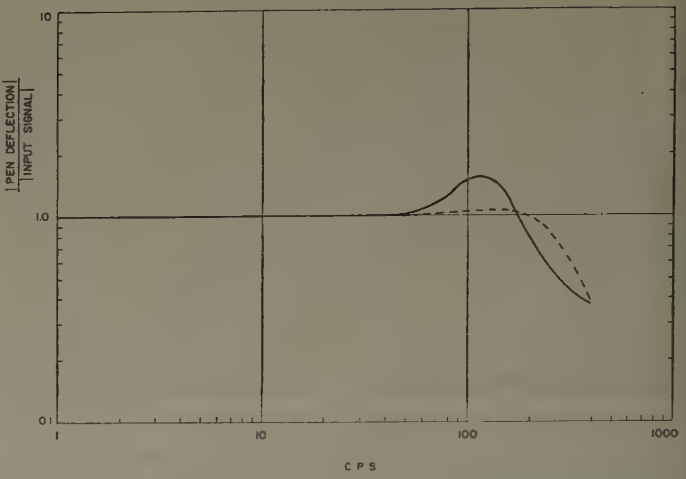


Figure 8. Frequency response for the complete Oscilloscribe; dotted line is for calculated values and the solid line for test values

Further procedures for modifying the moving system design are not quite so apparent since the three design considerations are variously affected by changes in the coil dimensions, the number of turns, the type of wire, and the wire size. Engineering optimization of the moving coil design is quite an interesting problem in itself. However, a discussion of this problem must be omitted here in the interests of brevity and clarity.

With objective 2 accounted for, the realization of objective 1 may be achieved by the application of standard servomechanism techniques.[6] Qualitatively the procedure involves making the open-loop transmission ratio appreciably greater than unity from direct current to 200 cycles. At the same time, however, care must be taken lest the phase shifts around the loop become excessive, with self-oscillation occurring as a result.

The magnitude of the open-loop transmission characteristic versus frequency (after initial adjustment of the amplifier gain) is shown in Figure 7. It can be seen that this characteristic is unsatisfactory since it exceeds unity up to only 80 cycles. A further increase of amplifier gain would result in instability however, due to excessive phase shifts. This situation is considerably improved by the insertion of a phase lead equalizer network, resulting in the open-loop transmission characteristic shown as a dashed line in Figure 7.

The over-all closed-loop frequency response of the system corresponding to this final open-loop characteristic is plotted in Figure 8 as a dashed line. The solid line in Figure 8 is the frequency response obtained by actual test of the final system. Although the actual system response does not agree precisely with the calculated response, it is, nevertheless, essentially uniform (within four decibels) over a range of frequencies from 0 to 220 cycles.

The reason for the disagreement between the actual response and the calculated response lies in the fact that the dashed line of Figure 7 does not accurately represent the open-loop transmission characteristic of the final system. Due to an unfortunate resonance effect in the slender shaft of the moving system, a very pronounced peak occurred in the response between the power amplifier and the detector output at a frequency between 400 and

500 cycles. This resonance effect coupled with the increased gain at these frequencies introduced by the phase lead network were sufficient to cause the over-all system to oscillate unstably at a frequency somewhere between 400 and 500 cycles. To eliminate this oscillation it became necessary to introduce a gain-reducing network which had to start becoming effective at about 150 cycles so that it could cause the required reduction of gain above 400 cycles. Since gain-reducing networks inherently introduce phase lag, it is evident that they considerably upset the phase characteristic and sufficiently reduce the system damping so as to cause a resonant peak of approximately 1.5 to occur.

The reduction of the resonant peak is thus a simple matter of a mechanical redesign of the moving system. The final result described here remains, nevertheless, a convincing demonstration of the effectiveness of position feedback in the development of high-speed direct-writing oscillographs.

SYSTEM PERFORMANCE

Several other aspects of the performance capabilities of this instrument are presented in Figures 9, 10, and 11. Figure 9 shows sinusoidal records at 26, 200, and 250 cycles per second. Calculations based on actual tests indicate that the instrument is capable of reproducing sine waves linearly with a full-scale amplitude of 2.5 centimeters for frequencies up to 50 cycles per second. Similarly calculations indicate that sinusoids up to at least 150 cycles per second can be reproduced linearly with a peak-to-peak deflection of 5 millimeters. Evidence that the instrument is indeed capable of clearly observable deflections at these high frequencies is presented in Figures 9*B* and 9*C*.

Figure 10 shows the records produced by the instrument in response to square waves. Transient response data can be obtained from the 16-cycle square wave record of Figure 10*A*. It can be seen that the pen reaches 67 per cent of its final position in less than 2 milliseconds, overshoots slightly, and then settles down completely within 5 milliseconds. Figure 10*B* shows that the record is very definitely a square wave even at 45 cycles per second while the record of Figure 10*C* showing a 60-cycle square wave is neither a sinusoid nor a square wave. The 60-cycle sine wave record of Figure 10*D* is shown by way of contrast to point out the presence of a considerable amount of third harmonic in the 60-cycle square-wave record.

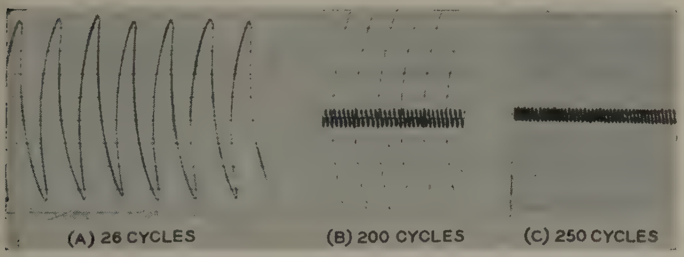

(A) 26 CYCLES (B) 200 CYCLES (C) 250 CYCLES

Figure 9. Records at frequencies indicated of sinusoidal input signals with chart speed 200 millimeters per second and large divisions on charts spaced at five millimeters

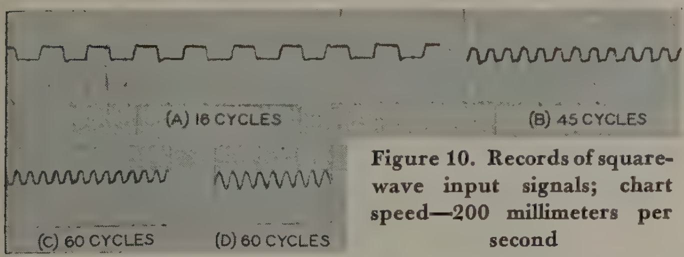

(A) 16 CYCLES (B) 45 CYCLES (C) 60 CYCLES (D) 60 CYCLES

Figure 10. Records of square-wave input signals; chart speed—200 millimeters per second

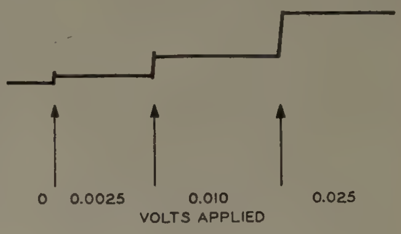


Figure 11. Drawing of record produced by several d-c input signals showing the over-all linearity of the Oscilloscribe and its freedom from frictional errors

The moving element is capable of developing a maximum torque of 2.8×10^5 dyne-centimeters at 0.1 ampere. When the loop is closed, an externally applied torque of 1.1×10^4 dyne-centimeters is required to deflect the pen 1 millimeter from its correct position. This high degree of stiffness considerably reduces the effect of viscous or coulomb friction on the pen's motions. Therefore, this system does not suffer the frictional errors which are present in open-loop recorders when the signal amplitudes are small. This is clearly demonstrated in Figure 11 where the input is constant but the attenuator setting is changed. This test also demonstrates the over-all linearity between the pen deflection and the voltage applied to the instrument. Drift after warm up has been observed to be less than 1 millimeter.

Because of its high static accuracies and its superior dynamic performance capabilities, it is believed that this type of recorder will find wide application in electrocardiography, electroencephalography, and the other rapidly developing fields of electrophysiology, servomechanism research and design, 60-cycle power system study, vibration measurement, nuclear radiation measurement, and many other fields.[7]

The authors wish to acknowledge the continued encouragement, during the course of this development, of Doctor J. L. Bower (M '45) of North American Aviation, Inc., formerly Associate Professor of Electrical Engineering at Yale University.

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Mapping Techniques Applied to Fluid Mapper Patterns

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FELLOW AIEE

FLUID MAPPERS can be built to simulate a wide variety of electrostatic, magnetic, and other analogous fields. The visible flow pattern shows the field conformation in terms of a large number of flow lines. Some of these lines can be traced by being selected so that the tubes formed can be mapped by simple and sufficiently accurate routines. The flow pattern for the map of Figure 1 was formed using an 8- by 12-inch slab. Thirty-three lines, forming an equal number of tubes, were traced from the flow pattern. Line selection is arbitary, leading to a collection of unequal tubes. Only accidentally will the relative ohms of two of the tubes be the same.

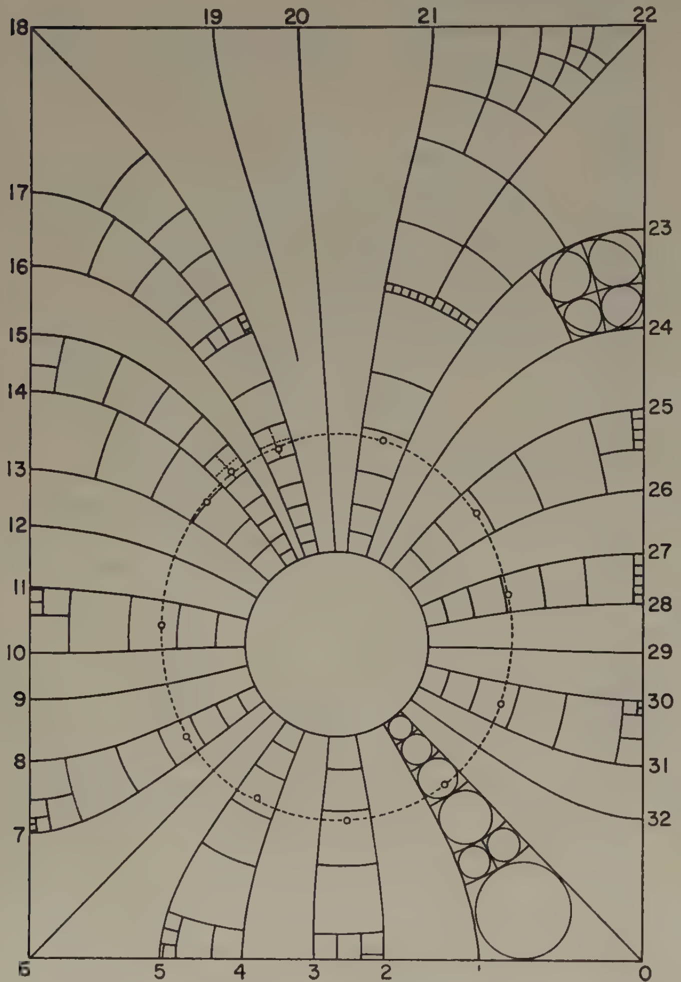

Figure 1. Map based on a fluid mapper pattern. Drawn to show a number of mapping techniques

Mapping a tube amounts to starting at one end and filling it with curvilinear squares, plus a remainder; then mapping this first remainder, if necessary, and leaving a second remainder to be mapped next if necessary, and so on. Several examples are shown in the map.

Constructing curvilinear squares is a rapid process when the circling-in method is used. The circles have been left in tube 0-1 to show the routine. A sectorial square (bounded by radii and arcs of circles) having an angle of 38 degrees or less can be circled in with an error of 2 per cent or less. Curvilinear squares having diagonal symmetry (symmetrical about one diagonal) are correct when circled in. When tubes are chosen properly, a large majority of the squares in most maps approximate to one or the other of these forms. The map shown is typical in this respect. The exceptionally distorted square always can be subdivided.

Curvilinear square volumes represented in a 2-dimensional map have three properties. First, there is the property of inversion: for flow taken either way, they have the same resistance. Second, they all have the same resistance. Third, for unit axial (or third) dimension, a curvilinear square volume has the same resistance as has a unit cube, for the same medium.

A tube, mapped as explained here, is evaluated easily since it is a series-parallel array of resistors. It often is convenient first to find its relative ohms by assigning one ohm to each curvilinear square volume. Absolute values for the curvilinear square volumes then can be found by use of the third property given.

Equipotential lines are derivable by simple routines. To derive the 50 per-cent equipotential in Figure 1, each mapped tube is made to say where it should cross. For example, tube 13–14 has six squares: this line should cross at precisely three squares out. The other tubes require interpolation.

These mapping techniques and methods of analysis are learned readily. They have been tested thoroughly by hundreds of the author's students and by others elsewhere. Ther usefulness has already been established.

With nothing more than simple graphical constructions and arithmetic, a map can be completed and analyzed for all numerical values. By taking the third dimension into account, 3-dimensional fields having axial symmetry and quasi-3-dimensional fields also can be solved.

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Permanent Magnets From Ultrafine Iron Powder

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Permanent magnets made from extremely fine powdered iron compare favorably with Alnico magnets and offer the advantage of much lighter weight. Present magnets of this material have only a fraction of the theoretically possible strength.

PERMANENT magnets composed of fine particles have had a fundamental interest for the past 15 years or so,[1,2] and have recently become of considerable practical interest because of impending shortages of nickel and cobalt. At first glance, the material is anomalous, in that pure iron, usually considered a means for obtaining high permeability soft iron magnets, is now formed into a hard permanent magnet.

The explanation for this behavior may be gleaned from the domain theory of magnetism, and before discussing the properties and problems of ultrafine powdered iron magnets, the highlights of this theory pertaining to such magnets will be summarized briefly.

OUTLINE OF THE DOMAIN THEORY

ALL FERROMAGNETIC substances, whether hard or soft, are considered to consist of domains (Weiss domains), as shown in Figure 1, which may be defined as a grouping of atoms in which the magnetic moments of the electrons, as a result of mutual interaction between these electrons of the atoms, lie parallel to each other. Each domain thus is magnetized spontaneously. In unmagnetized iron, the domains, each a permanent magnet, are oriented in complete randomness, yielding a net magnet moment of zero. This figure is oversimplified in that each grain contains large numbers of domains.

The size of these domains is a consequence of energy considerations, such that any domain will subdivide into two or more domains if the sum of the energies of these domains plus the energy of the boundary or wall in between is less than the energy of the original domain. This energy can be less and subdivision can occur if adjacent newly formed domains are magnetized in opposite directions (are antiparallel) as shown in Figure 2, each tending to reduce the demagnetizing field acting on the other.

The exchange energy between adjacent domains, this energy for wall formation determining in part the degree of subdivision of domains, will be less and the structure more stable if the entire change in spin directions between domains magnetized in different directions does not occur in one discontinuous jump across a single atomic plane but rather the change in direction takes place gradually over many atomic planes, as Figure 3 indicates. The domains in iron are estimated to be of the order of 1,000,000 to 10,000,000 Ångstrom units in width (0.01 to 0.1 centimeter) whereas the boundary or wall is estimated to be of the order of 1,500 Ångstrom units (about 1,000 atoms thick). A particle of iron whose diameter is of the order of that of a boundary, or Bloch wall, would be a single domain, and thus a permanent magnet, since the energy of the less

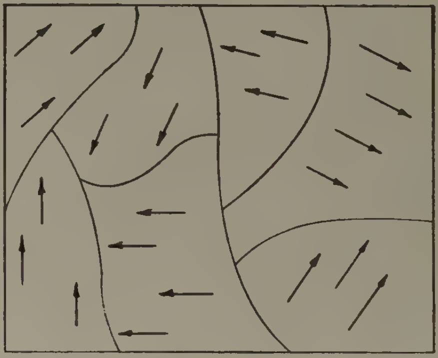

Figure 1. Random domain orientation in polycrystalline iron

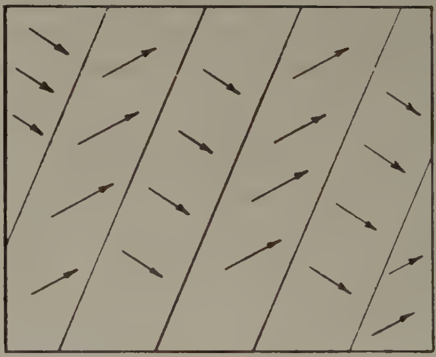

Figure 2. Domain structure within a single crystal

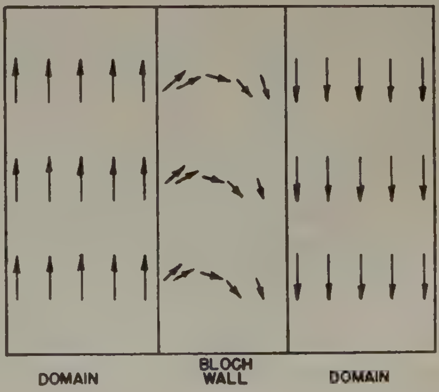

Figure 3. Boundary transition between domains

Full text of a conference paper, "Permanent Magnets From Ultrafine Iron Powder," recommended by the AIEE Committee on Basic Sciences and presented at the AIEE Winter General Meeting, New York, N. Y., January 21–25, 1952.

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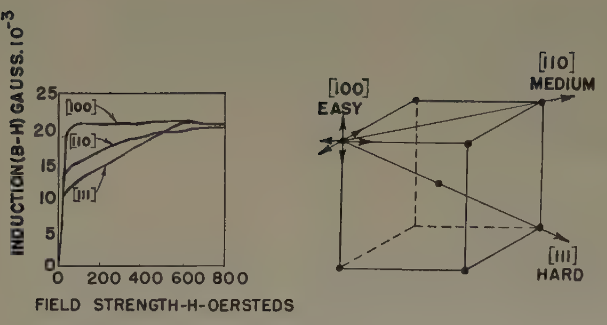


Figure 4. Directions of magnetization in iron

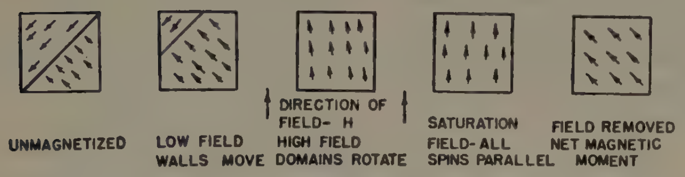


Figure 5. Wall movement and domain rotation resulting from magnetization

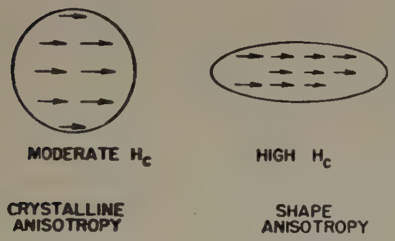


Figure 6. Single domain particles of iron

ordered wall is greater and therefore less stable than that of the ordered domain.

Of the three principal directions in cubic iron, the [100] direction is more easily magnetized (saturated at lower fields) than the [110] and [111] directions (Figure 4), and each domain in iron is considered magnetized spontaneously in the [100] direction. There are, of course, six [100] vector directions.

Upon application of an external magnetizing field, the boundaries or walls will move at low fields and the domains will rotate and tend to lie parallel to each other and to the field at higher magnetizing forces (Figure 5). Both these motions are such as to offer least resistance to the direction of the field.

Upon removal of the external field, there is a residual magnetic moment along those [100] directions which make the smallest angle with the direction of the field, because of the greater energy required for the domains to rotate through the harder [110] and [111] directions to return to their original position. Thus the retentivity is about half the saturation value. Meanwhile, the boundaries readjust themselves to form a structure of minimum energy, this energy being only slightly above the zero point energy for the case of soft iron, but considerably above the zero point energy for permanent magnet material.

It is partly the ability of the boundaries between domains in soft iron to move and adjust themselves to minimum over-all energy that first differentiates massive soft iron from ultrafine magnetically hard iron. To reverse the magnetization in a single domain, it must pass through the harder [110] and [111] directions of magnetization without benefit of moving boundaries to decrease the energy required. The coercive force of a number of single domain particles, defined as the force required to reduce the magnetization to zero, will be considerably larger than for massive iron. The greater the ratio of length to diameter of a permanent bar magnet, the greater its resistance to demagnetization (Figure 6). Therefore, if the particle, being a permanent magnet, consists of an elongated domain, such as in a prolate ellipsoid (cigar-shaped), its resistance to demagnetization is greater, and its coercive force is higher.

THEORETICAL CONSIDERATIONS

On the basis of these considerations, the conditions allowing for permanent magnet material from ultrafine iron powder may be stated.

Each particle must have a size of the order of that of a wall thickness and, therefore, be a permanent magnet with all its spins aligned. If the particle or domain is spherical, it must be magnetically anisotropic so that the domain cannot return readily to its original direction upon removal of the applied field. The greater the difference of demagnetizing energy between the easy and hard directions of magnetization, the greater the coercive force. If the particle or domain is elongated, the larger the ratio of major to minor axis, the larger the demagnetizing energy, and thus the larger the coercive force.

Néel,[3,4] Stoner and Wolfarth,[5] Kittel,[6] and others, have calculated on theoretical grounds the coercive forces expected when these factors are taken into consideration. These calculations are based upon a grouping of particles sufficiently removed from each other so that they exercise no demagnetizing influences upon each other.

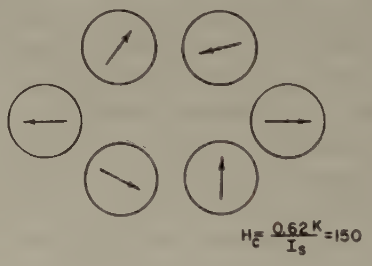


Figure 7(A). Single domain spheres with random orientation of domains

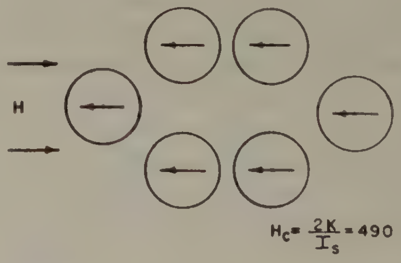


Figure 7(B). Single domain spheres with domains aligned

In the first case, Figure 7*A*, assume all the particles are spheres, and that all the domains are oriented at random. Then for case I*A*

$$H_c = \frac{0.62\,K}{I_s}$$

K is the anisotropy constant for iron, that is, the difference in energy between the easy [100] direction and the harder [110] and [111] directions of magnetization. K has a value of 4.1×10^5 ergs per cubic centimeter. I_s is the saturation intensity of magnetization of iron, and equals 1,700.

Substituting these two values

$$H_c=150 \text{ oersteds}$$

If this situation is modified, Figure 7B, so that the particles are still spheres but that the domains (magnetized in the [100] direction), are all lined up in their direction of hardest magnetization with respect to the external demagnetizing field, then for case IB

$$H_c=\frac{2K}{I_s}=490 \text{ oersteds}$$

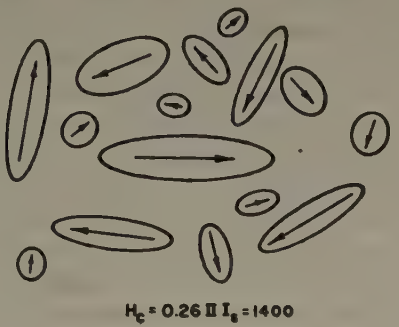


Figure 8(A). Single domain particles of random shape and random orientation

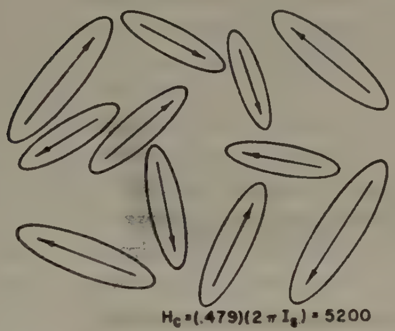


Figure 8(B). Elongated prolate ellipsoids with random domain orientation

If now the additional condition is considered that the particles not only may be spheres, but also elongated ellipsoids, the following values of coercive force are obtained.

In this particular case, Figure 8A, the particles consist of shapes varying all the way from spheres to highly elongated ellipsoids, and these particles or domains have random orientation with respect to the demagnetizing field. For case IIA

$$H_c=0.26\,\pi\, I_s$$
$$=1{,}400 \text{ oersteds}$$

If the additional restriction is made that all of the particles are highly elongated, that is, no spheres at all, but still randomly oriented, the difference in demagnetizing energy between long and short axes is further increased, Figure 8B, and for case IIB

$$H_c=(0.479)(2\pi I_s)$$
$$=5{,}200 \text{ oersteds}$$

If the further condition is imposed, Figure 9, that all the particles are highly elongated (long thin needles) and that all domains are oriented in the same favorable direction, the coercive force is estimated to be of the order of 15,000 oersteds.

These values may be considered the limiting values for very loosely packed powder. If the powder is compressed into a bar or other rigid shape, these values are to be multiplied, according to Néel,[4] by the factor $(1-d/d_o)$ where d_o is 7.9, the density of massive iron, and d is the density of the pressed compact. Usual pressing pressures of 40 to 60 tons per square inch yield a density of these pressed compacts of about 4, so that this correction factor is about 0.5.

Theoretically, at least, it is possible to produce ultrafine powdered iron magnets with coercive forces of 2,500 oersteds or better, with saturation magnetism B_s of the order of 11,000 gausses or so, and remanence of 5,000 gausses or better depending on the degree of domain orientation.

It should be pointed out that the contribution to coercive force as a result of strain is relatively low, even at very high strains, and is of no great consequence in materials of such high coercive force.

MAGNETIC PROPERTIES OF PRESENT MATERIAL

TO DATE, MAGNETS prepared from these ultrafine iron powders show $(BH)_{\max}$ values of the order 10^6 gauss-oersteds, compared to Alnico III of $(BH)_{\max}$ of 1.3×10^6 gauss-oersteds. These values are compared on a volume basis. Since the powdered iron magnets contain but 50 per cent iron, the magnets compare very favorably with Alnico III on a weight basis. The fullness factor, that is, $(H_cB_r)/(BH)_{\max}$, is about 0.3. The $(BH)_{\max}$ for Alnico V is 4.5×10^6 gauss-oersteds.

The values of coercive force can be varied somewhat with corresponding variations in remanence. Thus, magnets can be prepared with $H_c=500$, $B_r=5{,}000$, or $H_c=700$, $B_r=2{,}000$, or $H_c=200$, $B_r=9{,}000$. The $(BH)_{\max}$ of all these magnets is about the same. The coercive forces obtained are inversely proportional to the pressing pressure, since the farther apart the particles, the less the magnetic interaction.

It is apparent that the best ultrafine iron powder magnets to date are a far cry from the values which are theoretically possible, say $H_c=2{,}500$ oersteds, $B_r=5{,}000$ gausses.

PRACTICAL CONSIDERATIONS OF THE MATERIAL

TO UNDERSTAND THIS wide discrepancy between theory and practice, let us examine the nature of this powder

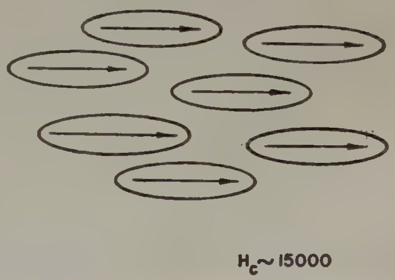


Figure 9. Elongated ellipsoids with domains aligned

and some of the difficulties which are associated in processing it.

First, consider the properties of this powder directly after manufacture and before magnetization. Since each particle is a permanent magnet, the particles will group together in clusters in such a way that the free poles neutralize each other and each cluster has a zero net magnetic moment. These clusters may be seen in the electron microscope, though resolution of particles 1,000 Ångstroms and less is so poor that definition is not too clear. A large number of the clusters appear as doughnut-shaped ringlets. Figure 10*A* is a schematic representation of this behavior, and Figure 10*B* is an electron microphotograph of the material.

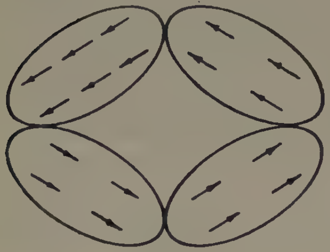


Figure 10(A). Clustering of single domain particles unmagnetized

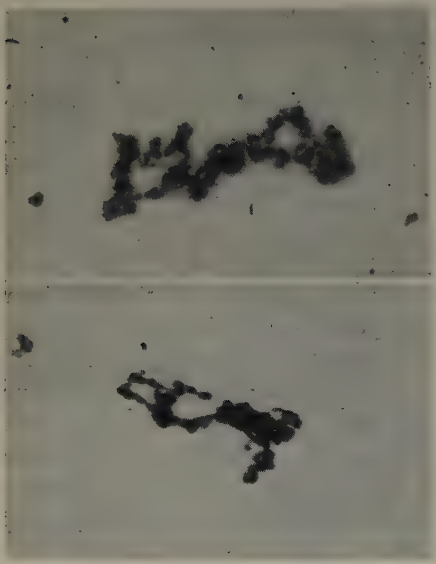


Figure 10(B). Electron microphotograph of clusters of ultra fine iron powder. Magnification-25,600× (top), and 31,000× (bottom)

The result of this neutralization is that the powder, before magnetization, behaves as a freely flowing powder, though it is not flowing as individual particles. This clustering of particles by strong internal fields has prevented, to date, the dispersion by any means of the powder into its ultimate particles.

During magnetization, Figure 11, the atomic spins of all domains are aligned in the direction of the field and upon removal of the field there is a net magnetic moment in the direction of the field, and a fairly high coercive force because of both the crystalline anisotropy and shape anisotropy of the domains.

Actually, the values of coercive force currently obtained, about 1,000 oersteds for loose unpressed powder (dropping to 500 at 50 per cent pressed density), are a long way from the 5,200 oersteds expected for randomly oriented highly elongated particles, and even further from the 15,000 oersteds for aligned domains. Electron microscopic observations with poor resolution reveal that the particles appear much closer to spherical shape than elongated ellipsoids and leave much room for improvement in further elongation of the particles.

The problem of aligning the particles, or domains, to effect further improvements, has not as yet been solved with any measure of success. It is obvious that such alignment involves physical motion of the particles with respect to each other so that they lie parallel. This requires some means of overcoming the very high magnetostatic energy between the particles in the cluster, and having once broken the cluster arrangement, keeping it broken until the particles can be aligned.

The several experiments to align the domains, by such obvious means as strong magnetic fields, heat treatment, and so forth, are of course attempts at improvement after establishing the properties of the powder as such. Prior to this must be considered the powder itself, that is, one in which the domain size of the particles is optimum, and the domain shape is elongated.

Néel[4] has studied theoretically, and Bertaut[7] experimentally, the dependence of coercive force on the size of the domains. Figure 12 shows such a plot, wherein it can be seen that maximum coercive force will be obtained at domain size of about 160 Ångstroms. This same value has been calculated theoretically by Néel. The data in this figure are for unpressed powder, and should be divided by a factor of approximately two for pressed bars.

This optimum size is obtained by reduction of ferrous formate with hydrogen at about 280 degrees centigrade. The time required for reduction is much too long for operation on a commercial scale, some 15 hours or so in a boat-type furnace. A temperature of 310 to 315 degrees centigrade represents an excellent compromise between time for reduction (5 to 8 hours) and coercive force. At this temperature range, the coercive force is not much lowered from its maximum value.

The particle size measurements in Figure 12 were obtained by X-ray line broadening. Figure 13 shows a comparison of particle size measured this way against results obtained by the Brunauer-Emmett-Teller method of gas adsorption. The theoretical dotted line at 45 degrees represents perfect agreement between the two methods of analysis. The actual curve obtained is quite close to this. The difference may be explained in several ways, most simply perhaps by the fact that the two methods use

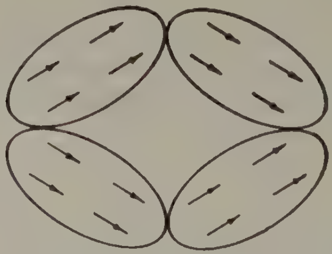


Figure 11. Cluster of single domain particles after magnetization

lifferent means for calculating an average particle size. \ somewhat more valid explanation assumes that the adsorption of nitrogen in the Brunauer-Emmett-Teller method is incomplete because it cannot penetrate to those surfaces which are agglomerated. A more complete description of the method and results is found in the paper entitled "Determination of Particle Size in Sub-Micron Range," scheduled for publication in an early issue of *Powder Metallurgy Bulletin* (Yonkers, N. Y.).

Considerable effort has been expended to date on means o modify the nature of the ferrous formate, the chemical tarting material from which the iron powder is obtained by reduction in hydrogen. It had been found some 10 years ago by the D'Ugine Company[8,9] of France that the co-recrystallization with the ferrous formate of certain other formates such as calcium or magnesium formates which are reducible in hydrogen only to their oxides will enhance the coercive force of the metal powder. Since he more effective oxides, called dopes, result in an iron particle size smaller than that obtained in reduction of undoped ferrous formate under the same conditions, this maller size explaining the higher coercive forces, the obvious mechanism of dope behavior is that it restrains intering together or agglomeration of the fine metallic particles being heated. This effect[10] has been known for more than 100 years. Doping agents other than those eported by the French have been found since, which are equally effective in reducing particle size and thereby enhancing coercive force.

In addition, certain other doping agents which increase he coercive force over and above the benefits obtained rom the usual doping agents have been discovered. To date, an improvement of about 15 to 20 per cent in $(BH)_{\max}$ has been realized. These novel doping agents do not affect the particle size. It is not certain yet as to whether they are causing an elongation in the shape of the particle, or whether they are modifying the cubic structure of iron towards a tetragonal structure. This latter effect would tend to increase the crystalline anisotropy effect. These doping agents are described in patent applications not yet filed.

SUMMARY

OUR PRESENT STATUS on ultrafine powdered iron magnets might be summarized in the following way.

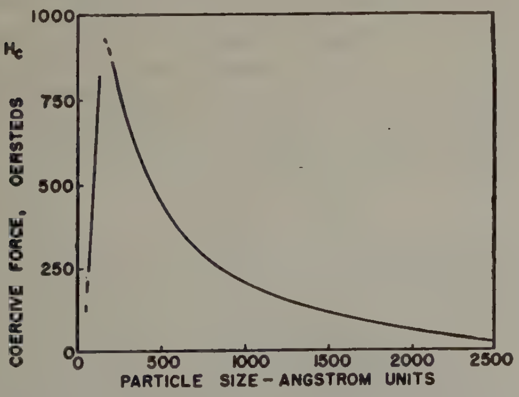
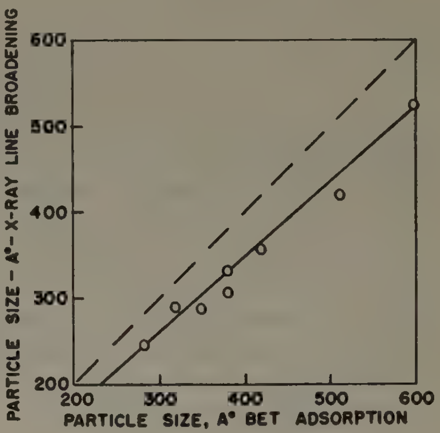


Figure 12. Coercive force as a function of particle size

First, iron powder can be made of that particle size, and thus domain size, which will produce essentially the maximum coercive force possible from the crystalline anisotropy of iron.

Second, from the fact that the coercive forces being obtained are somewhat greater than those expected theoretically from crystalline anisotropy alone, it is concluded that not all the particles or domains of the material are spherical.

Figure 13. Comparative particle size analyses



However, because the coercive forces presently obtained are relatively small in comparison with those predicted by theory, it is believed that the average ellipticity of the particles deviates only slightly from spherical. The present coercive forces can be explained by a ratio of minor to major axes of about 0.95, the value for a sphere being one, implying that only the surface has been scratched in domain elongation. Further elongation of domains will not come easily because surface tension forces, extremely potent in fine particles, will tend to keep the particles spherical.

Third, there has been no success in domain alignment. It is apparent that considerably more remains to be done than already has been accomplished.

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What Are the Opportunities in Engineering and Science?

CAREY H. BROWN

A TYPE OF ADVERTISEMENT quite unusual to the newspapers has been appearing with increasing frequency in the metropolitan dailies; the help-wanted advertisements for engineers and scientists. So far as the advertisements are concerned, they have been directed at engineers rather than scientists. Perhaps the engineer is considered more susceptible to the newspaper approach than his professional running-mate, perhaps he is considered less fixed in location, or both. These advertisements are evidence of the existing shortage of engineers and scientists. This shortage is acute in certain industries and areas, less acute in others, and perhaps for the time being, reasonably well satisfied in other localities.

Two factors—increased demand resulting from technological advances and decreased supply engendered by the falling birth rate and the interruption of the war years—are responsible for the current critical shortage of engineers. To attack this problem, we must supply our young people with the incentive to undertake an engineering career.

The qualifying phrase, "for the time being," is used advisedly since the shortage is destined to become more severe and more widespread in the years just ahead. In the vernacular, "things will get worse before they get better." This surely will occur in spite of the efforts of organizations such as the Engineers Joint Council, to improve the situation. The output of the engineering colleges up to and including 1955 is practically fixed by the present enrollment. Through transfers, or as a result of increased efforts to reduce mortality, the number of engineers graduating in the years 1952, 1953, 1954, and 1955 may be somewhat increased, but it will not be substantially so.

What is the prospect for graduates in these next four Junes? Based upon present enrollment in engineering courses and upon normal attrition, these figures can be stated quite definitely at 26,000 in 1952, 20,000 in 1953, and only 17,000 in 1954. These figures are in contrast to a class of 52,000 in 1950, all of whom were absorbed immediately. In 1955 the figure will be slightly higher than in 1954 but probably well under 20,000, unless there is an unprecedently high transfer rate resulting from increased appreciation by students now in college of the opportunities in engineering and science. Actually the expectancy of such transfers is limited. Usually the engineering curricula include mathematics and physics in the freshman year to such an extent that transfers from other courses would have difficulty in catching up on these subjects except at the cost of delay in graduation.

THE SHORTAGE OF ENGINEERS

THE FUNDAMENTAL CAUSE of the diminishing supply of engineering graduates is the low birth rate of the early 1930's. At the present time this affects not only engineering enrollment but college enrollment in general. We are now in the very trough of the curve of 17–18-year-olds. Possibly we may have passed the trough so far as engineering freshmen are concerned, since enrollment in 1951 slightly exceeded that of the previous year.

Another factor leading to decreased enrollment of engineers was the wall chart and data issued by the Bureau of Labor Statistics some two or three years ago, indicating that engineers would be in oversupply. These data were supported by the statements of some industrialists. However, they were based upon false conclusions as to the demands of American industry and the extent to which the large classes of engineering graduates resulting from the G. I. Bill would supply this demand.

In reality the postwar classes, supplying a peak of 52,000 engineer graduates in 1950, only served to offset the meager supply of the war years, when engineering training for able-bodied males practically ceased. Engineer graduates had reached a low of 8,000 in 1945. The policy of staying technical education during the war to provide men for the Armed Services was, to say the least, of doubtfu desirability. The long term results proved very serious The present shortage would be even worse except for the facts that the interruption was relatively short and tha G. I.'s flocked to the engineering schools after the war was over.

The result of all these factors is a present shortage o engineers estimated at 60,000 up—depending upon the degree of conservatism of the estimator. Present annua demand has been placed at 30,000 exclusive of the needs of the Armed Services. Graduations for some time to come will fall short of meeting the annual demand, to say nothing of cutting into the backlog.

Superimposed on this pent-up demand, we have the rapidly accelerating technological development which brings new demands, and new opportunities, to the engineer and scientist almost every day. That this is no

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Essentially full text of a talk before the Engineering Society of Detroit, Detroit, Mich., March 6, 1952.

Carey H. Brown, Manager, Engineering and Manufacturing Services, Kodak Park Works, Eastman Kodak Company, Rochester, N. Y., is Chairman, Engineering Manpower Commission of Engineers Joint Council.

merely a temporary condition is indicated by long term statistics as to the growth in numbers and importance of the engineering profession. These comments apply equally to the scientist. The work of one, in industry at any rate, is generally closely related to that of the other. The statistics quoted herein refer to engineers however, since the Engineering Manpower Commission has devoted more specific attention to them than to the general field of science. The ratio of engineers in industry to total industrial employees in 1890 was 1 to 300; in 1906, 1 to 200; in 1930, 1 to 100; and now, 1 to 50.

Where will it stop?

The impact of the Korean war and of the present defense effort is an important factor at the moment, but if the experience of World Wars I and II is of any value it teaches us that periods of such defense effort result in delayed demands for technological improvements in industry which serve to augment rather than diminish the demand for scientific and engineering talent when the war ends. Then there are the new fields resulting from the discoveries and research of the military establishment and its civilian employees.

To alert high school students to the opportunities in engineering and thus ease the critical shortage of engineers, more than 25,000 posters have been mailed to all of the secondary schools in the United States by the Engineering Manpower Commission of Engineers Joint Council. Here, T. A. Marshall, Jr. (left), Executive Secretary of the Engineering Manpower Commission, presents the first of these posters to A. G. Clausen, Jr., President of the New York City Board of Education, while B. G. A. Skrotzski, Chairman, Guidance Committee, Engineers Council for Professional Development, looks on

Engineering seems destined to continue its role as the fastest growing profession. The engineer is challenged by developments in atomic energy, television, and the whole electronic field, the new drugs, plastics, and metallurgy, jet propulsion, and the like, just as in the past he has been challenged by the steam engine, the railroad, the telegraph, the telephone, the automobile, the radio, the washing machine, the deep freezer, the combine, and other devices to increase the productivity of industry and agriculture, decrease manual labor, and generally add to the comfort and convenience of life. Exemplary of the advance in one relatively small field is the statement of a prominent manufacturing chemist that 90 per cent of the stock of a present-day pharmacy was unknown to the trade 10 years ago.

THE PROBLEMS INVOLVED

The problems with regard to the present shortage of engineers fall in general into two categories. The first relates to the utilization of engineers now available and the second relates to steps to be taken to increase the future supply.

The problem as to utilization of the present supply is very much complicated by the military situation. There is no means of assuring the use of engineers as such when they are called into service, whether through the draft, from the Reserve, or by other means. This results in undue depletion of the civilian supply. The Engineering Manpower Commission has endeavored to establish the principle that engineers in uniform must be directed into assignments which will fully utilize their engineering abilities. In addition to such efforts directed toward establishing the principle, the Commission also has presented for consideration a great number of individual cases of misapplication of engineering training and ability. Considerable progress has been made in this respect but the situation is not as it should be.

We cannot hope to match our potential enemies in numbers of men. We must out-design and out-produce them to emerge victorious. It is in our engineering, scientific, and productive skills that our superiority lies. Those elements of the military services who are particularly concerned with the development, design, and production of weapons are beginning to realize the impact upon their responsibilities of the present shortage of engineering and scientific personnel. Such realization on their part should go far toward persuading the military establishment itself that engineering and scientific talent must not be wasted. In line with the old "guns and butter" idea, it apparently has been the belief of the military establishment, at least until recently, that the concern of industry over the shortage of engineers is based on the fear that there would be a shortage of "butter." More and more it is being realized that unless steps are taken for the better utilization of technical skills there will be a shortage of guns as well as of butter.

It is not merely essential that technology develop and produce the weapons and equipment essential to the maintenance of military superiority. At the same time, it must carry out its major share in the development and production of articles of such attractiveness, usefulness, and serviceability to the civilian economy that the cost of military preparedness can be borne. The wreck of our civil economy would be as disastrous as military defeat. Maintenance of strength in our civil structure as well as in our military establishment is essential. In both, the role of the engineer is a dominant one, supply of engineering manpower is a critical problem, and failure to make full utilization of available engineering skills is a wasteful procedure which must be eliminated.

Efforts to secure better utilization of engineers in the Armed Services often are met with the accusation that private industry is doing a poor job in this respect. No doubt that is true in many cases. At the risk of being accused of taking a negative position with regard to utilization in industry, it is believed that we can look for best results, not as a consequence of any action which we can take now, but as a result of the workings of the law of supply and demand.

The nature of the activities of the various engineers engaged in sales, purchasing, and the like varies so much from place to place that it is impracticable to make any sound generalization with regard to justification for the use of engineers in such positions during an emergency. Two factors enter the situation. The first is that engineers who have been so employed for any considerable length of time probably now lack knowledge of the skills and techniques essential in the fields of design, development, and mechanical or chemical production, where our greatest needs exist. The second factor is that engineers who are nonessential in their present positions, whatever they may be, probably will be drained off into more essential engineering activities as the demand for their services makes itself felt. However, industry is urged to take all possible steps through upgrading of present engineers, shortening the period of training for new men, and so forth, to make possible the very maximum utilization of present personnel.

Provision of an adequate future supply of engineers constitutes an entirely different problem. The present shortage is so deep, and the prospective long range demand so great, that the attack upon this problem must be fundamental. The first requisite is to supply to our boys, and to a certain extent to our girls too, the incentive and the desire to undertake an engineering career. To accomplish this we must take steps to develop a more widespread knowledge of what the engineer does and of the importance of the engineering profession to the American way of life. America's high standard of living is due to its productivity. Here 6 per cent of the world's population produces 50 per cent of the world's goods. In this accomplishment the engineer's role is outstanding.

At the present stage in our history we have two major problems, which more or less merge into one. First of these is the successful solution of the military problem which now confronts us and which may be with us for some time. Second is the preservation of the American way and the American standard of life through this crisis and beyond, by further advance under the system of private enterprise and industrial development to which the engineer has contributed so significantly. There is much reason to believe that, while we heretofore have considered ourselves as living in the technological age, we actually only have been approaching that age. Recent advances in science have been so rapid that the engineer is challenged as never before. It is our function to translate these advances into means for the survival of our civilization and for an ever-improved standard of living. The engineer's role, his opportunities and responsibilities, ar
destined to become greater and greater as science continue
its advance.

THE WORK OF THE ENGINEER

OUTLETS FOR THE SKILL of the individual engineer ar
varied. The scientist and the engineer co-operat
in research and development. Design of buildings
machines, equipment, and installations of all sorts is th
engineer's primary function. It is entirely logical howeve
that the engineer finds his place in the fields of production
sales, or service. Many an industrial establishment
particularly those engaged in the production of machiner
or mechanical equipment, feels that most of its majo
activities should be headed by engineers. Engineers hav
unusual opportunities to rise to the positions of top management in industry as is so clearly evidenced by the number
who have done so. The military services and the civilia
branches of government offer many opportunities. Civi
engineers in particular find a major outlet for their worl
in the activities of highway construction, water supply
sewage disposal, and so forth, which are to a large exten
the concern of governmental agencies.

The maintenance of a continued and adequate suppl
of qualified engineers depends upon the ability, personality
and competence of teachers furnished by the engineerin
profession.

One of the engineers from Eastman Kodak Compan
recently returned from a trip to several of the engineerin
colleges to interview members of the 1952 class relative t
employment. He states that many of these young me
have received a dozen or more offers. Reserve Officer
Training Corps members are in many cases employed b
industrial firms who are quite willing to take the risk o
temporary loss of such men to the Armed Services. A
portion of this frantic rush at the moment is due to th
demands of defense production, but in the main it reflect
the ever-increasing technological demands of America
business and industry. The great increase in labor rate
in the past few years have made continued advance i
mechanization essential to survival in a competitive system
As manufactured articles come within reach of more an
more people, sales and employment have increased. Nev
discoveries and inventions increase rapidly, and thei
demands upon the scientist and upon the engineer are exceptional.

It is this expanding economy of ever-increasing productivity that is America's pride and America's hope fo
the future. Within the life span of many readers th
normal work week has been cut almost in half, considerin
hours of work, vacations, holidays, and the like. Th
back-breaking tasks have been largely absorbed by mechanization. For much of this the engineer is responsible
He should aspire to preserve this way of life through whic
the material comforts and conveniences provided by a
system of free enterprise may be made available to mor
and more of the world's people. In such a world th
engineering profession will face challenge—and opportunity—as never before.

Safe Electric Appliance Design Principles

G. E. SCHALL, JR.   W. C. WALSH

Accomplishment of a renaissance in everyday living is due to the modern electric household appliance which performs time-consuming tasks and provides many luxuries and comforts. Such appliances are used and often misused by technically uninformed persons and so the design must incorporate safety features to take such factors into consideration.

TECHNOLOGICAL developments, improvements in manufacturing methods, and the advent of cheap electric power is the combination fostering the vastly increased use of the home appliance. By definition of the National Electrical Code, this appliance is: "Current-consuming equipment either fixed or portable; for example, heating, cooking, or small motor-operated equipment." In periods of change or improvement, desires of the consumer are often whetted to the point that the demand for the new equipment exceeds existing production. These periods bring to the forefront many inexperienced people who undertake the task of supplying the demand. As a result, the public may be exposed to appliances with hazards of construction and performance which are below acceptable minima.

One phase of Underwriters' Laboratories operation is the judgment of electric equipment under its standards from the standpoint of fire and accident hazards; to safeguard such hazards; and to determine that the product may be installed in accordance with the provisions of the National Electrical Code.

Most equipment used by the general public in the United States is designed for connection to circuits of 250 volts or less (125 volts to ground) and, if motor-driven, includes a fractional-horsepower motor. This discussion will be based upon experience accumulated during the judgment of equipment under the requirements of the Heating Appliance Standard and the Motor-Operated Appliance Standard of Underwriters' Laboratories, Inc., and intended for installation by the rules of the National Electrical Code. The National Electrical Code is fundamentally a utilization code intended to cover the safe use of electric power in home and industry. Various sections, however, outline constructional requirements or set forth provisions of operation which can be met only by correct design and manufacture of electric equipment.

The applicable portions of the Code and many other requirements relating to the production of safe appliances are set forth in Underwriters' Laboratories, Inc., Standards. These standards are minimum in nature (not how poor a device may be, but the essentials of reasonable and generally attainable excellence), and are not intended to be qualitative measures of appliance performance. It is possible for two similar appliances, complying with the requirements of the standard, to be widely divergent with respect to initial cost, efficiency, economy, ease of operation, and even total useful life; and yet both be considered safe with respect to fire and accident hazards incident to their everyday use.

RATING

THE RATING of an appliance is the manufacturer's formal indication of the power requirements of that particular appliance while performing its intended function. It is the inspection authorities' guide when computing the current-carrying capacities and overcurrent protection of the branch circuits, and verifying proper voltages and frequencies.

Appliances should be correctly rated. Incorrect ratings may result in overheating of supply circuit wiring insulation and nuisance tripouts of branch-circuit protectors with consequent annoyance to the user who may react by increasing the size of the protector, or by removing it completely from the circuit. Such results may endanger both the user and the other occupants of the building.

SUPPLY CONNECTIONS

AS NOTED previously, appliances may be portable or stationary. They should be designed for connection to their source of supply in a manner suitable and proper for everyday operation.

Flexible cords have a definite place in such connections and may be used on appliances where portability is essential. Cords also may be used on relatively stationary equipment where servicing requires ease in interchange, or noise abatement is desired. There are approximately 56 recognized types of flexible cords. The National Electrical Code and the Standards of Underwriters' Laboratories specifically indicate the various types of cords suitable for use with the different kinds of portable domestic and commercial appliances on the basis of serviceability, temperature ratings, and flexibility.

The proper type of cord for the portable appliance being manufactured, the correct wire size for the conductors in accordance with the current carried, and a suitable attachment-plug cap for connection to the corresponding

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Essentially full text of conference paper recommended by the AIEE Committee on Safety and presented at the AIEE Winter General Meeting, New York, N. Y., January 21–25, 1952.

G. E. Schall, Jr., and **W. C. Walsh** are with the Underwriters' Laboratories, Inc., New York, N. Y.

receptacle (which is a part of the branch-circuit wiring) are items of prime importance. Flexible cords are basically not as safe as permanent wiring since they are much more susceptible to deterioration as a result of aging, abuse, and exposure.

Appliances not intended to be moved, or which are interconnected with other utility services, such as water and gas, normally should be provided with wiring terminals or pigtail leads, a terminal box, and a means for the termination of one of the wiring methods recognized in the National Electrical Code so that they can be permanently connected to a branch circuit of the needed capacity.

The means of attachment of the supply source to the appliance should be readily available for installation and for future inspection by the authority having local jurisdiction over the wiring of electric installations. It should not be necessary for inspectors, in performing their work of checking electric installations, to move fixed appliances or to remove parts of the building itself to determine that safe electrical practices have been followed in making the splices and connections to the supply wiring.

GROUNDING PROVISIONS

CORRECT GROUNDING of electric equipment is another important feature of the installation of appliances. Article 250 of the National Electrical Code is one of the prime sources of information relative to proper grounding procedures.

The reason for grounding equipment is apparent once its function is understood. It is common practice in the United States today to connect to ground one of the conductors of the circuit used to bring power to residences or places of business—that is, to bring one conductor in intimate contact with the earth (usually at the service entrance to the building) through water pipes, grounding rods, or buried metallic objects. Such an arrangement results in the other supply conductor assuming a potential above earth, or ground, equal to the actual voltage existing between the supply conductors.

Most appliances have metallic enclosures or other exposed parts of conductive material. If the appliance is not in good electric contact with the earth, an insulation breakdown or other defect could cause exposed metal parts to become energized by the live conductor and thus assume a potential above ground equal to the supply circuit potential. Any person standing on a grounded surface or contacting a grounded object (such as a water faucet), and touching the appliance would be exposed to the voltage existing on the enclosure and become a path for whatever current could flow.

Proper grounding of the appliance would result in leakage currents flowing directly from the live conductor to the enclosure and through the grounding means back to the other grounded supply conductor. The circuit overcurrent protector then usually will act to open the circuit as soon as the fault occurs within the appliance.

All appliances intended for permanent connection to a source of supply should be designed and constructed so that they may be grounded properly. Such grounding usually is accomplished by supplying the appliance through conductors enclosed in a grounded metallic raceway. Grounding also can be obtained by means of separate conductors.

Portable appliances present a different problem with respect to grounding since there is no universal use (in the United States) of a type of attachment-plug cap and receptacle assembly which automatically provides a grounding connection when the portable appliance is plugged into the receptacle. A new type of receptacle assembly has been developed and is now in production which will accommodate both the conventional 2-parallel-blade type of attachment-plug cap usually found in appliances, and also a new cap incorporating two parallel blades and a U-shaped grounding blade. It is expected that the use of the new receptacle will result in use of the new 3-pole cap and eventually it will supplant the older type of receptacle and cap assembly which offers no grounding facilities.

If reliance is placed on grounding of appliances in homes as a protective means, grave difficulties can be encountered if breakdowns occur to the enclosures of the appliances when the appliances are not actually completely grounded. In such a case, a person contacting the "live" case of the appliance and at the same time touching a positively grounded object would become a parallel path in the grounded return of the leakage current with the possibility that his body would carry enough current to cause death.

Additionally, most surfaces in homes are of insulating material or are not in any way grounded. As a result, the chance of contacting a grounded object, except in the bathroom or kitchen, is considerably less than in industrial establishments.

Surveys have indicated that most electric shock accidents in the home have been the result of the victim becoming the path between a grounded object and an actual live part (such as the screw shell of a lampholder), rather than an appliance enclosure which has been made "live" because of internal breakdown.

Appliances constructed with superior types of insulation would resist the breakdown voltages and sudden surges which are encountered in such installations. The chances of the breakdown occurring prior to the time the equipment is no longer serviceable then could be reduced.

NORMAL HEATING

EACH APPLIANCE has a normal function which involves an indeterminate number of, or a predetermined repetition of, complete cycles of operation.

In the safe design of electric appliances, care must be taken to insure that the product will perform its intended function for a reasonable length of time, or number of complete cycles, without overheating of the various materials used for electrical insulation. Further, the appliance must not become a hazard with respect to surrounding material or surfaces with which it may be in contact.

Electrical insulation used for the mounting and enclosure of live parts is segregated into several classes of insulation, such as organic, semiorganic, and inorganic materials. These classes have been separated further according to the maximum recommended continuous temperatures which the insulation will stand without deterioration, in such publications as the AIEE Standard Number 1, The National Electrical Code (particularly cords and wiring), and the Standards of Underwriters' Laboratories, Inc.

Mounting surface temperatures and adjacent walls must be below the limits for which wood is considered acceptable. This is usually 90 degrees centigrade for fixed appliances and 150 degrees centigrade for those appliances not likely to remain in one position. These temperature limitations result from observation of the effect on a combustible surface of the steady application of heat over a long period of time. Temperatures above these limits may result in a formation of a self-igniting type of charcoal known as pyrophoric charcoal.

The lower the temperature at which the charring process occurs, the lower the temperature will be at which the charcoal later may ignite spontaneously. Moisture, present during the charring process, may hasten the oxidation and subsequent ignition.

The duration of a normal heating test is determined by the use of the appliance in service. Many domestic appliances, and all commercial equipment, are considered to operate continuously and must do so without overheating of the electrical insulation or the surrounding materials. However, certain specific pieces of equipment, such as electric mixers, dishwashers, washing machines, and so forth, which have an intermittent use in our everyday home life, fall within the class of equipment which is acceptable after performing a set number of complete cycles of operation. The total number of cycles set is more severe than is likely in the use of the appliance in the home.

Various types of cooking appliances are operated with temperatures on the cooking surfaces equivalent to those which are normally experienced in high-temperature types of cooking. Commercial equipment of this class is tested in alcoves or other areas of restricted ventilation such as might normally occur in service.

DIELECTRIC STRENGTH

Even while connected to a branch circuit of proper voltage the electrical insulation of an appliance may be subjected to voltages in excess of the marked rating of the appliance. These voltages are intermittent in nature and are due to transient conditions existing on the circuit or to line surges caused by lightning strokes adjacent to the power lines. All such voltages tend to apply momentary stresses which may break down over the surface of, or through, inferior electrical insulation within an appliance. Such breakdowns may result in failure of the appliance to operate or in the enclosure being made alive by being connected directly, or through a leakage path, to the live electric conductors.

The purpose of a dielectric-strength test performed at a voltage above rated voltage is to determine that adequate spacings between live parts and dead metal parts and sufficient types and thicknesses of insulation have been employed. It also assures that there is a measurable safety factor employed in the construction of the appliance to assure a sufficient margin between the actual operating voltage and the breakdown voltage of the insulation to take care of line surges, reduction of creepage distances due to deposits of dust and dirt, and general decrease in insulation characteristics as a result of aging and wear.

To protect the appliance user against the shock hazard which could result from contacting live parts, the proper types of insulation should be used at all points where conductors may come near metallic frames and enclosures of the appliances. Where no over-all solid insulation is provided on live parts, such parts must be reliably mounted on insulating materials so that there will be no possibility of shifting during normal usage to reduce the prescribed air spacing to the nearest uninsulated grounded metal parts or the creepage distance (oversurface spacing) between the live part and the nearest grounded metal surface.

Many types of recognized insulating materials are available for enclosing or mounting live parts to take care of almost all of the more common voltages and temperatures found in appliances today. Each type of insulation, while rated for a specific maximum continuous voltage for its normal duty, can be designed in sufficient thicknesses or quantities so that the appliance as a whole will withstand transient conditions for long periods without a dangerous flashover or breakdown between live parts and the exposed metal parts of the enclosure.

Selection of the proper type of insulation is dependent on such factors as the temperature, voltage, presence of moisture, water spillage, and accumulations of conductive dust. Noncarbonizable material should be used at all points where a possibility of a momentary flashover exists so that, once the flashover has cleared itself, there will be no resultant tracking of the insulating material.

INSULATION RESISTANCE

Equipment is often called upon to function while exposed to the "weather" or in moisture-laden or steam-saturated atmospheres. Where portable equipment may be in intimate contact with persons or where steam or other vapors are present during the normal usage, the types and thicknesses of insulation and the oversurface distances between the uninsulated live parts and the metallic frame and enclosure should be great enough so that the continuous current leakage is maintained at all times below 5 milliamperes.

It should be understood that 5 milliamperes does not represent an imperceptible leakage current when passed through the human body. On the contrary, it is well within the perceptible range of most persons. However, experience and tests have indicated that such a current, when passed through the human body, does not constitute a safety hazard. Good manufacturing practices, and concern over consumer resistance to an appliance which tends to "shock" them each time they contact the frame and another grounded surface, usually are factors which require manufacturers to maintain, at points of likely contact, current leakage values well below the 5-milliampere limit acceptable from a strict hazard standpoint.

ABNORMAL HEATING

The general public at times misuses appliances in such a manner that they become fire and accident hazards.

Such misuses may occur during absence of the user, thus increasing the danger which might result from a failure of the machine under abnormal conditions. It is therefore necessary that abnormal conditions of operation be taken into consideration during design The simplest procedure is to determine the ultimate results of such abnormal operation. If a fire will not necessarily occur, it is good practice to prevent unusual deterioration of the appliance which will create hidden shock hazards of a nature eventually affecting the user.

If a fire occurs, then it is necessary to guard against this hazard. Such guarding may be through the use of reliable temperature-limiting thermostats, or various types of overcurrent protectors, or redesign of the appliance itself to eliminate the hazard.

Whatever limiting means is required and employed in the unit should be suitable and reliable for its intended usage. Temperature-limiting devices should be fixed in calibration in a manner not susceptible to tampering by the user. Overcurrent protectors, where required, should be of the so-called nontamperable type which cannot readily be removed.

Misuse of a wall-insert-type bathroom heater is a good example of abnormal operation. While functioning normally with an unrestricted air flow, the temperatures on the surrounding wall surfaces and the temperature of the air emanating from the front of the heater are maintained at acceptable levels. However, if a towel is draped across the front of the heater, as might possibly be done, then the flow of the heated air from the heater would be blocked and, if an inherent thermal protector were not provided by the manufacturer to disconnect the appliance from the circuit, the air temperatures would be raised gradually to such a point that the towel might be ignited and the temperatures on the surrounding wall surfaces would reach hazardous values.

CONSTRUCTIONAL FEATURES

THE CONSTRUCTION of electric appliances must take into consideration the function of the various parts which make up the appliance. The enclosure normally supports and encloses the electric and mechanical operating parts of the device, while the operating components, electric and otherwise, perform the assigned task of the machine.

Both together should result in a construction which will resist the abuses involved in normal or likely abnormal use of the appliance, and will protect the user from harm which would result from contact with live electric or moving mechanical parts. Further, the enclosure should be of a substantial nature and design which will offer suitable protection if abnormal conditions, such as burnouts or short circuits, should occur within the appliance.

All materials entering into the construction of an appliance, particularly the frame and enclosure, should be of a type suitable for the application and, if other than those normally used (such as metals), should be of a type which will provide the required ruggedness and which will not, in themselves, add to fire or accident hazards which may occur as a result of usage of the appliance.

Underwriters' Laboratories has been quite concerned over the use of combustible materials in the construction of appliances. It is recognized that small quantities of combustible types of material are not usually harmful. However, it has been found difficult to determine where a small quantity becomes large enough to be considered a fire hazard and it is almost impossible to draw a line at a point where different types of small combustible parts can be considered to combine into one large mass of dangerous combustible material.

From a practical standpoint it is desirable to use noncombustible parts unless it can be shown that the combustible materials employed will not increase the fire hazards normally associated with the appliance under consideration. As an example, a small piece of combustible thermoplastic material inserted in a metal enclosure as a decorative effect is not dangerous or harmful. However, as the size of the plastic is enlarged, it becomes a problem to determine when the piece should be considered a vital part of the enclosure and when its size is of such a nature that it will maintain a fire once it has become ignited.

Ventilating openings or other access holes which are intended to be employed during the normal operation of an appliance should be so located or otherwise shielded to protect the operator and others who might be in proximity to the machine from inadvertent contact with uninsulated live parts or with the mechanism. These ventilating openings should not permit flame transmission to combustible materials outside the enclosure itself.

If combustible materials are incorporated in the appliance, ventilating openings must be considered from the standpoint of the oxygen supply available to support combustion in the event of an internal fire.

Electrical spacings are an important part of the construction of an electric appliance. As indicated under Insulation Resistance and Dielectric Strength Tests, such spacings are a factor in maintaining proper creepage distances between live parts and the enclosure of the appliance and are necessary to prevent or minimize the chances of flashovers occurring as a result of transient voltages.

Live uninsulated parts within an appliance should be rigidly supported on the proper types of insulating materials and should be spaced well away from other parts of opposite polarity, or from the enclosure, so that, under likely conditions of use or misuse, the spacings will not be decreased to a point where the frame and enclosure will become alive. The spacings should be sufficient to anticipate reduction through a gradual deposit of conductive dust on the insulating materials which otherwise would result in breakdown of the insulation oversurface.

Spacings in appliances vary with the class of appliance. It might be expected that variations in spacings would occur only according to the voltages involved and the materials used. However, spacings are the outgrowth of years of experience in various industries. To arrive at safe limits for spacings, it has been necessary to draw upon this experience and set up spacing requirements which reflect common practices in the particular industry involved. Where different types of appliances are subjected to the same general conditions of use, attempts are being made to arrive gradually at a common set of spacings which will be applicable to all of the appliances. This is necessarily a long-time task since each change of this type involves economic adjustments on the part of each individual manufacturer.

MARKING

An electric device must indicate its electrical rating. This rating should include the voltage and frequency for which it is intended, so that it may be safely and correctly utilized by the public. The current or power consumption should be indicated also so that an informed user, or the inspection authorities having local jurisdiction, will be able to anticipate its demands on the branch circuits to which it will be attached.

A catalogue number or other specific designation of the actual model is also an essential part of the marking since it serves the manufacturer when necessary to correspond with a purchaser regarding replacement of component parts and aids in the identification and recognition of equipment that has met reasonable safety requirements.

Underwriters' Laboratories, as part of its service to the electrical industry, lists, by marked catalogue numbers and manufacturers identification, equipment found to meet the minimum standard requirements with regard to fire and accident hazards. The listing serves to indicate those appliances which have been considered acceptable and makes it possible for the general public or inspection authorities to check for listed equipment. Further, the Underwriters' Laboratories' inspectors, as part of the factory inspection program under Re-examination Service, make use of the catalogue numbers as a means of identifying the listed equipment in the manufacturer's factory and when checking such equipment are able to determine that its construction remains at the same level as the samples originally investigated.

CONCLUSION

An attempt has been made to bring into sharp focus those features of appliances, intended for use by the general public, which often are a cause for comment when judged under the requirements of Underwriters' Laboratories, Inc. There are special problems pertaining to many types of equipment, each requiring individual consideration. These are too numerous to be discussed here.

Certain constructions remain essential in safe electric appliances for use by the general public. The equipment should be designed to be energized correctly and safely for installation under the provisions of the National Electrical Code. Design and construction should protect the user and others from the hazards which might result from contact with uninsulated live parts or unguarded mechanisms. The safe design of an electric appliance should take into account the fact that it eventually will wear out and, when it does, its failure to operate should result in no accident hazards or be contributory to external fires.

REFERENCES

1. National Electrical Code. National Board of Fire Underwriters, New York, N. Y., Pamphlet Number 70, January 1951 edition.

2. General Principles Upon Which Temperature Limits Are Based in the Rating of Electric Machines and Apparatus. AIEE Standard Number 1, June 1947.

3. Standard for Electric Heating Appliances. Underwriters' Laboratories, Inc., New York, N. Y., fifth edition, January 1949, and Revisions.

4. Standard for Motor-Operated Appliances. Underwriters' Laboratories, Inc., New York, N. Y., first edition, April 1937, and Revisions.

5. Grounding of Portable Equipment, Article 250 Committee. *News Bulletin* of the International Association of Electrical Inspectors (Chicago, Ill.), January 1947.

Proposed Changes in Standard Tests for Transformer Dielectrics

AN AIEE COMMITTEE REPORT

Standards in any field must be amended as progress is made. Presented here are proposed changes in transformer insulation tests now under consideration by the AIEE Standards Committee and the American Standards Association Sectional Committee C-57.

The AIEE Committee on Transformers has under consideration various changes in the dielectric tests on transformers. Much progress has been made in the art, and it is natural that the earlier standards need to be amended from time to time. The changes as given here have been proposed by the Insulation Tests Subcommittee of the AIEE Committee on Transformers and have been forwarded to the AIEE Standards Committee and the American Standards Association Sectional Committee

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Full text of a report prepared by the Insulation Tests Subcommittee of the AIEE Committee on Transformers. Members of the subcommittee were F. J. Vogel, *Chairman;* J. A. Adams, V. J. Christen, J. E. Clem, I. W. Gross, J. H. Hagenguth, D. C. MacGregor, W. R. McCarty, J. R. Meador, C. W. Miller, V. M. Montsinger, W. C. Sealey, and W. L. Teague.

C-57. These proposals are now being voted on by the latter group as a revision in the American Standards for Transformers, Regulators, and Reactors, and are published here for the information of the Institute as to the progress of the work.

PROPOSED CHANGES

Add a new insulation class to Table 11.030 with values as follows:

Column 1...180
Column 2...104
Column 3...180
Column 4...180
Column 5...360
Column 6...—
Column 7...—
Column 8...—
Column 9...950
Column 10...3.0
Column 11...825
Column 12...950
Column 13...3.0
Column 14...825

Change 11.034(f) as follows:

The standard impulse test on the neutral of a transformer designed for Y connection, when brought out through a bushing, will consist of one reduced full wave and two full waves having a crest voltage for the insulation class of the neutral, provided the size of the neutral bushing permits. This test on the neutral will be made only when specifically called for.

If the insulation class of the highest voltage neutral bushing for which provision is made is different from the insulation class of the neutral end of the winding, the impulse test voltage will be for whichever insulation class is lower.

When applied directly to the neutral, the test waves shall be 1.5x40-microsecond waves. When induced in the neutral by the application of 1.5x40-microsecond waves to other terminals, the wave-shape shall be that resulting from the characteristics of the winding. If the neutral ends of windings are specified for alternate or future connection as line terminals, standard tests shall be applied to the neutral as outlined in *11.034(e)*.

The foregoing paragraphs also apply to the terminals of the series windings of separate regulating transformers, or other similar devices to be located in the neutral. If the series windings have taps, tests should be made with maximum turns in the windings.

Change 11.034(h) as follows:

When apparatus covered by this Standard are to be assembled in a common tank and interconnected, the complete assembly shall be tested as a unit of 100 per cent of the lowest test voltage required by any of the components.

Change 11.035 as follows:

(a) Reduced full wave test.

For this test, the applied voltage shall have a crest value of 50 to 70 per cent of the full wave value given in the table which appears in each section of these Standards.

(b) Chopped-wave test.

(1) For this test, the applied voltage wave shall have a crest voltage and time to flashover in accordance with the table which appears in each section of these Standards.

(2) The chopped wave shall be obtained by flashover of the bushing or of an external rod gap.

(c) Full wave test.

For this test, the applied voltage wave shall have a crest value in accordance with the table which appears in each section of these Standards.

Delete 22.112(b).

Change 22.114(d) to be as follows:

In the case of transformers having one end of the high-voltage winding grounded, the other windings should be grounded during the induced-potential test. This ground on each winding may be made at a selected point of the winding itself or of the winding of a step-up transformer which is used to supply the voltage or which is merely connected for the purpose of furnishing the ground.

Change 22.114(e) to be as follows:

Three-phase transformers may be tested with single-phase voltage. The specified test voltage is induced, successively, from each line terminal to ground and to adjacent line terminals. The neutrals of the windings may or may not be held at ground potential during these tests.

Change 22.114(f) to be as follows:

When the induced test on a winding results in a voltage between terminals of other windings in excess of the low-frequency test voltage specified in Table 11.030, the other windings may be sectionalized and grounded in accordance with *22.114(a)* to *(e)*. Additional induced tests shall then be made to give the required test voltage between terminals of windings that were sectionalized.

Change 22.115(b) to be as follows:

The time to crest on the front from virtual time zero to actual crest shall not exceed 2.5 microseconds except for windings of large impulse capacitance (low voltage—high kva and some high voltage—high kva windings).

To demonstrate that the large capacitance of the winding causes the long front, the impulse generator series resistance may be reduced, which should cause imposed oscillations. Only the inherent generator and lead inductances should be in the circuit.

Replace 22.115(f) with the following:

When there are high-frequency oscillations on the crest of the wave, the crest value shall be determined from a smooth wave sketched through the oscillations. If the period of these oscillations is 2 microseconds or more, use the actual crest.

Replace 22.115(g) with the following:

If there are oscillations on the front of the waves, the 30- and 90-per-cent points shall be determined from the average, smooth wavefront sketched in through the oscillations. The magnitude of the oscillations preferably should not exceed 10 per cent of the applied voltage.

(With superimposed oscillations of high magnitude, evaluation of wave crest is difficult, while if generator characteristics are such as to give a completely smooth wave, it may be difficult to detect failures of small portions of the winding insulation by means of the cathode-ray oscillograph. If the impulse generator is sufficiently flexible, a good compromise is the use of generator constants such that the transformer impedance largely determines the length of the tail of the applied wave.)

22.115(h) will be the same as 22.115(g) in present Test Code as follows:

All impulses applied to a transformer shall be recorded by a cathode-ray oscillograph if their crest voltage exceeds 40 per cent of the crest of the full wave in accordance with *11.030* and Table 11.030. When reports require oscillograms, those of the first reduced full wave, the last two chopped waves, and the last full wave of voltage shall represent a record of the successful application of the impulse test to the transformer. See *22.116(c)*, *(d)*, and *(e)*.

Change 22.116 to be as follows:

(a) The standard tests consist of applying in the following order: one reduced full wave, two chopped waves, and one full wave. (Exception *22.118.*)

(b) Impulse tests are to be made without excitation unless excitation is specified. If excitation is specified, the impulse shall be timed within 30 electrical degrees of the crest of the normal voltage of opposite polarity.

(c) Reduced full-wave test.

For this test the applied voltage wave shall have a crest value of between 50 and 70 per cent of the full-wave value given in the table which appears in each section of these Standards.

(d) Chopped-wave test.

For this test the applied voltage wave shall be chopped by a suitable air gap. It shall have a crest value and time to flashover in accordance with the table which appears in each section of these Standards.

(e) Full-wave test.

For this test the voltage wave shall have a crest value in accordance with the table which appears in each section of these Standards, and no flashover of the bushing or test gap shall occur.

(f) The time interval between application of the last chopped wave and the final full wave shall be minimized to avoid recovery of insulation strength if a failure has occurred prior to the final full wave.

(g) To avoid flashover of the bushing during adverse conditions of humidity and air density, the bushing flashover may be increased by appropriate means.

Change 22.117(b) to be as follows:

(1) Terminals not being tested (no excitation).

One terminal of the winding under test shall be grounded directly or through a low resistance if current measurements are to be made. (For exceptions see *22.117(c)* and *22.120.*) The terminals of the winding that are not being tested may be grounded directly or through a resistor in order to limit the voltage induced in these windings. It is desirable that the voltages on terminals that are not being tested should not exceed 80 per cent of the full-wave voltage for their voltage class.

(2) Terminals not being tested (with excitation).

One terminal of the winding under test shall be grounded. One terminal of each of the other windings may be grounded. It is desirable that the voltage on ungrounded terminals shall not exceed 80 per cent of the full-wave voltage for their voltage class.

All ungrounded terminals shall be protected, if necessary, by appropriate means, such as lightning arresters.

(When lightning arresters are used for limiting the voltage, they may cause a divergence between the reduced full wave and the full wave that interferes with failure detection, see *22.121.* That this divergence was caused by the lightning arrester may be demonstrated by repeating the reduced full wave, the chopped waves, and the full wave without excitation and with the lightning arresters short-circuited or replaced by resistors.)

Change 22.117(d), (e), (f), and (g) to be as follows:

(d) Windings for series or multiple connection, if either connection is in the 25-kv insulation class or above, shall be tested on both series and multiple connections. The test voltages for the two conditions shall be that corresponding to the insulation class of the winding for that connection. For voltage class 15 kv and below, only the series connection shall be tested unless tests on both connections are specified. The connection of the other windings (whether series or parallel) shall be made at the choice of the manufacturer.

(e) Tap connections shall be made with minimum effective turns in the winding under test. The choice of tap connections of windings not being tested shall be made by the manufacturer. Regulating transformers, step-voltage and induction-voltage regulators shall be set at maximum buck position.

(f) When protective devices are permanently connected as an integral part of series transformer windings or of other portions of windings, these devices shall be connected during test. The operation of these devices usually will cause differences between the reduced full wave and the full-wave oscillograms. That these differences are caused by the operation of the protective devices may be demonstrated by making two or more reduced full-wave tests at different voltage values to show the trend in their operation. Further evidence that the differences are due to the operation of the protective devices may be obtained, in some cases, by making additional tests with the protective devices short-circuited out. When the nature of the protective devices and the design of the transformer permit, the impedance of such devices may be varied for the full-wave and reduced-wave tests as an optional refinement in the technique of failure detection (*22.121*).

(g) Windings of very low impedance.

In some cases, the inductance of the winding is so low that the desired voltage magnitude and duration to the 50-per-cent point on the tail of the wave cannot be obtained with available equipment. In some cases, the terminals of such windings having the same insulation class at both ends may be tied together for the test. Because of the difference in insulation class at the two terminals of the winding, it is sometimes impossible to tie the terminals together for the impulse test. Low inductance windings also may be tested by inserting a resistor of not more than 500 ohms in the grounded end of the winding. In all such cases shorter waves may be used.

Change 22.118 to be as follows:

Impulse Tests on Transformer Neutrals.

(a) Impulse tests on the neutral of a transformer or a separate regulator connected in the neutral of a transformer may be applied by the methods given below. The choice of the method of testing the neutral shall be made by the manufacturer.

(b) Low-frequency excitation shall not be applied for the test on the neutral.

(c) Method of test.

1. The test on the neutral, or neutral and regulating winding, is induced by the application of an impulse to any line terminal with the neutral grounded through a suitable impedance so that the required full-wave test voltage is obtained from the neutral terminal to ground. One reduced and two standard waves shall be applied to the line end of a winding with a crest voltage equal to or less than the full-wave level of the line end. The other windings may be short-circuited for this test. The winding being tested shall be on the maximum voltage connection. The voltage oscillograms shall be taken at the neutral. When this method of test is used, the test on the neutral shall precede the test on the line terminal.

2. One reduced and two full waves are applied directly to the neutral or regulator winding with an amplitude equal to the insulation level of the neutral. The winding being tested shall be on the maximum voltage connection.

Change 22.121 as follows:

Detection of Failure During Impulse Test.

Because of the nature of impulse test failures, one of the most important matters is the detection of such failures. There are a number of indications of insulation failure. Some of these are

(a) Voltage oscillograms.

Any unexplained differences between the reduced full wave and the final full wave detected by superimposing the two voltage oscillograms, or any such differences observed by comparing the chopped waves to each other and to the full wave up to the time of flashover, are indications of failure. Deviations may be caused by conditions in the test circuit external to the transformer or by protective devices (*22.117 b-2*) and (*22.117f*) and should be fully investigated.

(b) Smoke and bubbles.

Smoke bubbles rising through the oil in the transformer are definite evidence of failure. Clear bubbles may or may not be evidence of trouble. Clear bubbles may be caused by entrapped air. They should be investigated by repeating the test, or by reprocessing the transformer and repeating the test to determine if a failure has occurred.

(c) Failure of gap to flashover.

In making the chopped-wave test, failure of the chopping gap, or any external part, to flashover, although the voltage oscillogram shows a chopped wave, is a definite indication of either a flashover within the transformer, or in the test circuit.

(d) Noise.

Unusual noise within the transformer at the instant of applying the impulse is an indication of trouble. Such noise should be investigated.

(e) Ground current oscillograms.

Ground current measurements may be made at the discretion of the manufacturer. When this method of detection is used, the impulse current in the grounded end of winding tested is measured by means of a cathode-ray oscillograph connected across a suitable shunt inserted between the normally grounded end of the winding and ground. Any differences between the current waves obtained on reduced full waves and full-wave tests detected by superimposing the two current oscillograms may be an indication of failure. Deviations in the current waves may be caused by conditions in the test circuit external to the transformer, or by built-in protective devices (*22.117f*) and should be investigated fully. It is difficult to shield the measuring circuit completely from the influence of the high voltage of the surge generator and some stray potentials are frequently picked up which may produce an erratic record for the first 1 or 2 microseconds. Such influences, if they occur at the start of the current wave (and to a less extent at the start of the voltage wave), should be disregarded.

The ground current method of detection is not applicable for use with chopped-wave tests, or when the transformer is excited during impulse tests.

(f) Excitation of the transformer during impulse test.

The transformer may be excited during the impulse test. The normal frequency voltage may result in noise or smoke sufficient to be detected by excessive current or drop in voltage in the normal frequency excitation circuit. Best results in failure detection by this means will be secured when the source and associated transformers are of the largest practicable kilovolt-ampere capacity.

Processing Mica Paper for Electrical Insulation

R. L. GRIFFETH E. R. YOUNGLOVE

For more than a half century various improvements have been made in built-up mica insulation—splitting mica into thin films and cementing them together to form large sheets. A significant advance in micaceous insulation is the new continuous mica sheet described herein.

MICA IN the form of continuous thin, coherent sheets will soon make its appearance as a component of electrical insulation. The use of mica in this unique form constitutes a significant advancement in the modern concepts of micaceous insulation.

The birth of the "Electrical Age" with Edison's early model of a motor and generator proved the importance of mica as an insulation medium. At that time, large mica splittings comprised only 5 per cent of mica mine output and the growing electrical industry was soon hard pressed to find a sufficient supply. In 1892, Jefferson and Dyer conceived the idea of splitting the smaller grades of mica into thin films and cementing them together to form large sheets of various sizes and thicknesses. Since that time, many improvements have been made in built-up mica insulation but most of these have been in the field of bonding agents. Built-up mica insulation still utilizes machine- or hand-laid mica splittings. The invention and use of continuous mica sheets is the greatest advancement in mica insulation in over 50 years.

The credit for first processing mica into continuous sheets belongs to a Frenchman, Jacques Bardet. With Bardet's discovery, as with so many other discoveries and inventions, the result of his investigations was not the one which he expected. He was seeking to make mica dust by treating mica thermally and chemically, but upon filtering and drying he found not a mica dust, but a coherent sheet. Much of the development work which was necessary to perfect the coherent sheet of mica was carried on during the German occupation of France. The fact that a continuous mica sheet was being developed was kept secret from the occupation forces and all of the raw and finished materials had to be smuggled in and out of France. After the occupation, plans were rushed to put the laboratory phenomenon of continuous mica sheets into pilot-plant production.

The production of mica in this novel form is in some ways not unlike the conventional manufacture of paper from wood pulp. The raw material for these mica sheets is muscovite mica in the form of domestic and mine waste, scrap, or recovered mica. The mica is first heated to a temperature sufficient to induce its partial dehydration, but the temperature of heat treatment must not be sufficient to produce total dehydration. The exact temperature and time of thermal treatment is dependent upon the source of the mica. For each mica there is a well-defined optimum temperature and time of treatment. The loss of some of the water of crystallization modifies the crystal and produces a noticeable swelling of the mica. The thermal treatment requires extreme care because of the necessity of heating the mica to a very uniform temperature throughout the mass.

As the hot mica emerges from the treating furnace it is quickly immersed in a saturated solution of sodium carbonate or bicarbonate. The local boiling in this solution expels the air from the interlamillar structure of the mica, already swelled as a result of heating. Upon cooling, the mica appears as thin layers scarcely adhering to each other and retaining a large amount of the alkaline solution. To prevent excessive waste of alkaline solution, the mica is allowed to drain for a short period before immersion in a strong solution of hydrochloric acid or sulphuric acid. The resultant gaseous reaction puffs the mica to a very great extent. Puffing in the order of a hundred times the original thickness of the mica film is common. The coherence of the strata of mica in this state is very weak and only washing and agitation are required to produce a pulp suitable for the formation of a coherent sheet of mica.

Rolls of continuous thin mica sheet (Figure 1) can be made on a conventional Fourdrinier type of paper machine.

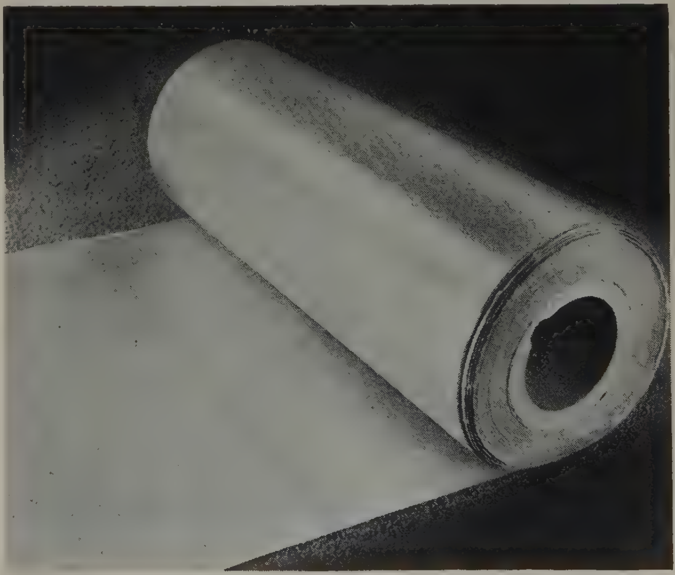

Figure 1. A roll of silvery mica sheet, extremely uniform in weight and thickness

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Revised text of conference paper recommended by the AIEE Dielectrics Subcommittee of the AIEE Committee on Basic Sciences and presented at the AIEE Winter General Meeting, New York, N. Y., January 21–25, 1952.

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A small amount of a special melamine formaldehyde resin in an acid colloidal dispersion is necessary to give the mica structure sufficient strength for processing and also to improve wet strength. In this form there is a similarity between sized cellulose paper and long continuous mica sheets.

The mica sheets are composed of a large number of mica layers of extreme thinness, of the order of a few hundred thousandths of an inch. Some of the mica flakes attain a surface area as large as one-tenth of a square inch.

The continuous mica sheet as it comes from the paper machine has about one-half the density of natural mica because of the interposition of air between the elementary layers. The tensile strength of the sheet is variable and depends on the source of the mica and its treatment. Mica in this novel form does not compare with mica splittings in mechanical or electrical properties as it comes from the machine, but in combination with suitable bonding agents, products can be made which are superior to conventional electrical insulation now being made with mica splittings.

In processing mica sheet into articles of finished insulation, it has been found that products which have heretofore been difficult to manufacture with mica splittings are now easy to produce with mica in continuous roll form. For example, one of the best illustrations of the versatility of mica sheeting is its use as a component in a silicone molding plate. For the last few years, as the emphasis has been placed more and more on silicone insulation, manufacturers of micaceous insulation have tried to produce a silicone hot-molding plate which could be used for ground insulation on motors and generators. This then was apparently an excellent spot for continuous mica sheets to be tried. Using an experimental silicone resin which had proved unsuccessful for this application with mica splittings, molding plates were made with these mica sheets. Channels and commutator V-rings were easily formed or molded (Figure 2) after heating pieces of the hot molding plate for a few seconds at 165 degrees centigrade. The channels have been kept in a standard laboratory atmosphere for periods well over six months and at a relative humidity of 96 per cent for over two months with no apparent change in shape. Using rolls of uniform mica sheet, it has been possible to produce molding plates of very uniform thickness without surface milling. The silicone hot-molding plate can also be molded to other more intricate shapes without difficulty. The dielectric strength of an 18-mil silicone molding plate with 2-mil glass on each side is about 1,900 volts per mil of thickness with very little difference between the maximum and minimum values.

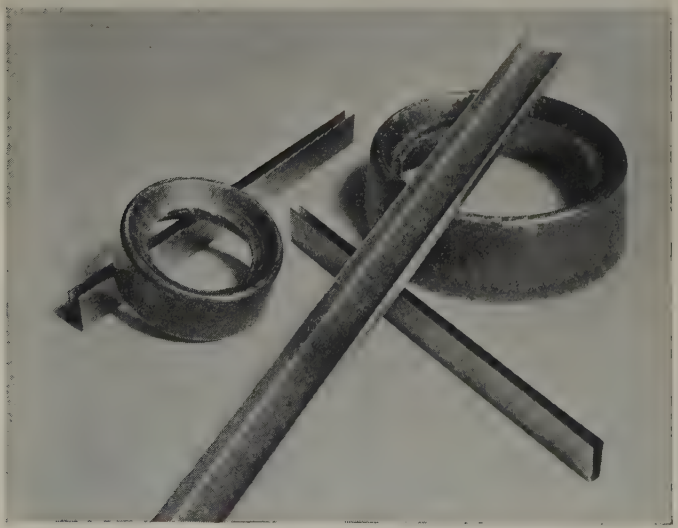

Figure 2. Channels and commutator rings formed from built-up mica sheets

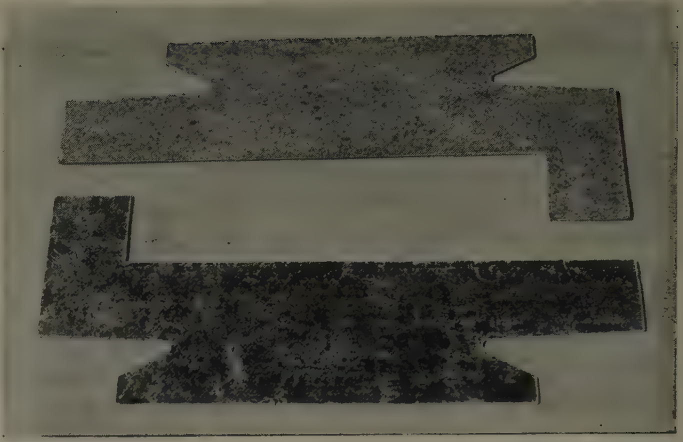

Figure 3. The upper segment is the new mica insulation; the lower, mica splitting insulation

The coating of mica from continuous rolls is achieved by either spray or dip coating. With dip coating, a process which is impossible with mica splittings, it is possible to attain a very uniform distribution of binder over both surfaces of the sheet. The uniformity of the sheet and coating makes possible a uniform cure. Pressed plates from the coated mica sheets are very homogeneous and devoid of pockets of shellac or other binder. Such pockets have always been a source of trouble in older types of mica insulation. In laying up plies of a uniformly coated sheet, it could be expected that the finished plate would be extremely uniform in thickness. Experience in handling the continuous mica sheets has shown that in many products surface milling to thickness is unnecessary. Uniformity of thickness of these products, combined with inherent homogeneity, undoubtedly will reduce the necessity of conducting high-potential tests on each sheet as is now required in many customers' specifications for micaceous products. The homogeneity and uniformity of thickness are two great advantages which will be realized through the use of mica in this improved form.

Another outstanding example of homogeneity and uniformity of thickness is the commutator segment plate which is made from this improved insulating sheet. When compared with a standard (National Electrical Manufacturers Association) Grade 3 muscovite segment plate the new mica plate is characterized by: 1. lower density; 2. greater uniformity of thickness; 3. compressibility about equal; 4. excellent compressive strength at elevated temperatures; 5. better punchability; 6. higher accuracy of fabrication in sawing, milling, and so forth; 7. lower hardness; and 8. more uniform bond content.

The lower hardness of this new type of mica segment plate is a result of the partial dehydration of the mica during the paper-making process. This lower degree of hardness suggests that the wear of commutator segments will be practically the same as that of the copper. The final answer, relative to the necessity of undercutting commutator segments made with mica in this new form, can be determined only through functional evaluation of this new product.

The homogeneity of the mica sheet decreases the danger of sliding of the mica or oozing of the binder because pockets of binder or concentrations of mica can be completely eliminated. In small segments of relatively heavy thickness, the splitting and flaking of micanite products has always been a source of trouble, especially in assembly operations. However, similar segments produced from continuous mica sheets show no tendency to split or flake. Figure 3 shows the new mica segment and a segment composed of mica splittings.

The dielectric strength of a 32-mil segment plate is about 1,200 volts per mil. This value is double the NEMA value for average dielectric strength of a standard mica segment plate. Because of the homogeneity of the new product, the dielectric strength is uniform not only throughout a single sheet, but is also uniform from sheet to sheet.

Tapes can now be made from rolls of continuous mica in almost all of the combinations where mica splittings are used. In discussing the value of tape made from mica in this new improved form, the emphasis is again on uniformity. The uniformity of the continuous mica sheet eliminates the high and low thickness spots which are always present in tapes made with mica splittings. Such a uniformity in thickness allows a very neat and compact wrapping on coils and bars. The dielectric strength of these improved mica tapes does not show the wide variations that are commonly found in tapes made with mica splittings. Tapes made from a continuous mica sheet do not have the voids that have long proved a source of trouble to both manufacturer and consumer. A roll of silicone-bonded mica tape composed of Fiberglas cloth and continuous mica sheet is shown in Figure 4 with a roll of standard silicone-bonded mica tape composed of Fiberglas cloth and mica splittings.

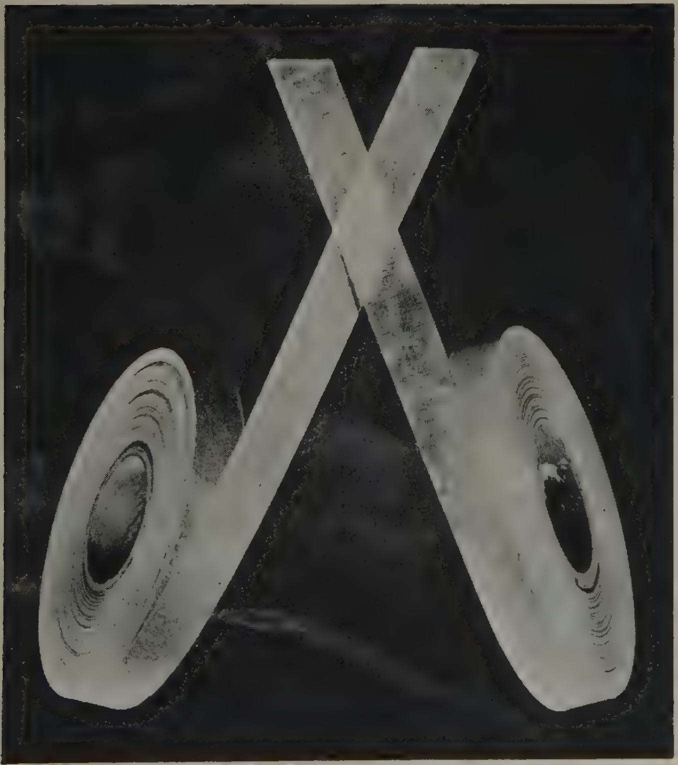

Figure 4. Silicone-bonded mica tape composed of Fiberglas cloth and continuous mica sheet on the right, and standard silicone-bonded mica tape composed of Fiberglas cloth and mica splittings on the left

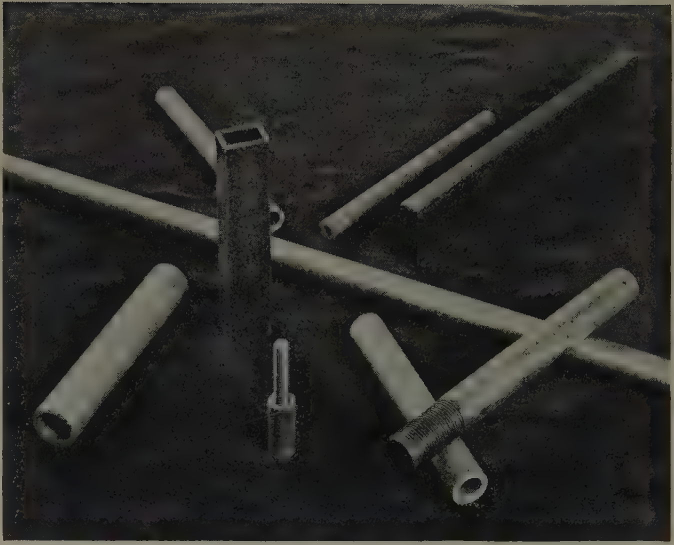

Figure 5. Miscellaneous rods and tubes made from the new form of continuous mica sheet. These mica products can be machined, punched, tapped, or threaded

Many other forms of electrical insulation have been made from mica-based sheets. For instance, rods and tubes, such as shown in Figure 5, can be easily machined, punched, drilled, tapped, or threaded.

New varieties and forms of mica insulation can be made by using mica paper. For example, many items of so-called "specialty insulation" which formerly have not been made with mica splittings now can be made with this new form of mica. At the present time, it is believed that eventually this form of mica can replace mica splittings in all grades of micaceous insulation and also will find new uses in electrical insulating products where mica splittings cannot be used successfully.

The strategic value of these novel mica products in the present confused international picture is important. Mica is listed as a strategic mineral in rather short supply. With a large part of our muscovite mica coming from India, the inclusion of India in the Russian sphere of influence would pose a very serious problem of supply. Mica paper can be made from domestic mica of many sources. If the cold war should suddenly get hot, enemy action could make transportation of mica from India hazardous and an imported mica would not be obtainable in adequate supply. This new form of mica could certainly make up for the loss of Indian mica in most of our micaceous insulation.

Control of a 65-Watt 2-Phase Servomotor With a Magnetic Amplifier

F. S. MALICK

A self-saturating magnetic amplifier circuit is described for the control of a 2-phase 400-cycle motor. Major design factors are minimum weight, low power consumption, long life, and a 10-cycle response.

A SERVOMECHANISM having a maximum power output of 65 watts was needed for an airborne application. It should have the minimum possible weight and the lowest power consumption consistent with reliability, long life, and a 10-cycle frequency response.

The 2-phase servomotor drive seemed best for this application. Hydraulic servomotors are too heavy for this low power output and no clutch was readily available.

The motor used is an Oster-type *2DTHC-484* 115-volt 400-cycle 2-phase motor rated at 2 amperes per phase at a stall torque of 21.5 ounce-inches. The power input at stall is 115 watts per phase and the maximum speed is 11,000 rpm. Motor and blower weigh 6 pounds.

POSSIBLE METHODS OF MOTOR CONTROL

Thyratrons. Four methods of controlling the power into the control phase of the motor were considered. Thyratrons were ruled out largely because ripple in the control signal may cause erratic operation and partly because of the large heater power required at standby.

Vacuum Tube Amplifier. The vacuum tube circuit of Figure 1 required a total of 3.5 pounds of transformers, a relatively large volume to house the tubes, and a heater power of 75 watts. The over-all efficiency is 50 per cent.

Simple Reactor Bridge. The simple reactor magnetic amplifier circuit of Figure 2 was built and tested and found to give satisfactory motor control. When a d-c signal is placed on the tube grids to cause tube V_1 to conduct, reactors 1 and 2 become saturated by the flow of plate current so that the motor control winding is effectively connected across the a-c supply. Reversing the polarity of the signal applied to the grids causes reactors 3 and 4 to become saturated while reactors 1 and 2 become a high impedance so that the control winding is connected across the a-c supply in the opposite polarity, reversing the motor.

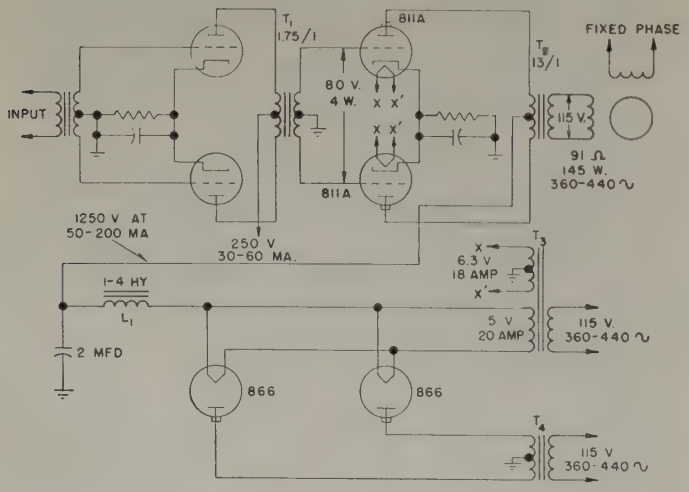

Figure 1. An electronic circuit for the control of the 65-watt 2-phase servomotor

This simple circuit has a number of disadvantages. As in all simple reactor amplifiers, the average a-c ampere-turns on the reactor must equal the average d-c control ampere-turns. In the design which was tested, 60 milliamperes were required in 22,000 turns to obtain the desired 2-ampere motor current. The *6AQ5* tubes which were used required a ±25-volt d-c signal on the grids. In this particular servo a d-c amplifier having the required voltage gain could not be built with a convenient tube lineup. Considerable plate and filament power is required and the time delay is somewhat longer than for a self-saturating circuit. The toroidal reactors are hard to build because of the large number of control turns needed.

Self-Saturating Bridge. The circuit finally chosen is the much used[1] self-saturating circuit of Figure 3. The total weight of the reactor unit, autotransformer, and rectifiers is 5.5 pounds. Because of the large power gain of the self-saturating circuit, a control current of 6 milliamperes in 1,200 turns is all that is required for full output. The *5744* subminiature control tubes required only ±1 volt on the grid. This circuit, in common with the simple reactor circuit, was unaffected by large amounts of ripple on the signal applied to the tube grid.

One parallel self-saturating magnetic amplifier, sometimes called a "doubler," is used for each direction of rotation. When amplifier 1 of Figure 3 is saturated, the motor is effectively connected across one-half of the transformer. Amplifier 2 then has high impedance and has a total voltage across it equal to the voltage of one-half of the transformer plus the voltage across the motor. Reversing the polarity of the signal applied to the tube grids reverses the situation so that the current in the motor control winding changes phase 180 degrees to cause the motor to run in the opposite direction.

Essential text of a paper recommended by the AIEE Committee on Magnetic Amplifiers and presented at the National Electronics Conference, Chicago, Ill., October 22–24, 1951.

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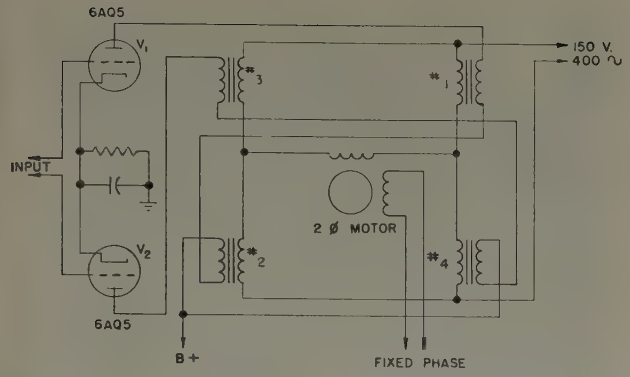

Figure 2. Bridge circuit using saturable reactors for control of the servomotor

The linearity of the motor-torque versus signal curve is improved if the bias is adjusted so that a circulating current of about 0.4 ampere flows through the two amplifiers when the motor current is zero. This type of amplifier will give full output unless bias ampere-turns are applied to reduce the output. If the bias fails, both amplifiers have a low impedance, thus effectively short-circuiting the transformer. The current which flows can be many times the maximum motor current and may burn out the rectifiers or the reactors.

THE DESIGN OF THE AMPLIFIER

ON THE BASIS of previous experience it was estimated that the transformer voltage applied to each amplifier should be about 50 per cent greater than the voltage which was desired on the motor. This extra voltage is lost in resistive drop in the reactors and rectifiers and permits the amplifiers to be operated in the linear portion of the transfer characteristic, that is, up to about 80 per cent of their maximum output. The transformer voltage was therefore made 175 volts on each side of the center tap.

The reactors then should be designed for a transformer voltage of 175 volts plus the maximum motor voltage of 115 volts or 290 volts. On a 400-cycle a-c system having ±5 per cent voltage and frequency regulation, the reactors would be designed for 305 volts at 380 cycles.

If a magnetic amplifier is used for power control, as in this instance, the reactor may be described completely by specifying the voltage at which the power winding of the reactor saturates and the resistance of the power winding. The best reactor design is the one which has the lowest weight for a given power winding resistance. This assumes that a large control power is available so that power gain need not be maximized.

A large number of reactors were designed using cores made from 0.5-inch Hypernik V strip with various outside and inside diameters. From the results of these designs as plotted in Figure 4, the design which gives the minimum reactor weight for a given power winding resistance can be selected. On the basis of about 14 volts maximum resistive voltage drop, a power winding resistance of 7 ohms is desired. In position servomechanism service the reactor must be designed for large peak outputs. It was estimated that with a 7-ohm power winding resistance the low average power output would not heat the reactors to their 50-degree-centigrade allowable rise. For this particular power winding resistance a core having an inside diameter of 1.5 inches and a 0.5-inch-square cross section is convenient and has almost the minimum weight. A core having a 0.375- by 0.5-inch cross section would give an equivalent reactor weighing 27 per cent more.

A similar study using aluminum wire showed that an equivalent reactor could be built weighing 20 per cent less. Unfortunately aluminum wire was not readily obtainable in the small sizes. The control and bias windings were wound with number 36 wire because it is the smallest size wire which is easy to wind on a core of this size.

The rectifiers are rated to carry 1.2 amperes continuously. Because a servomechanism is an intermittent duty device, it was felt that it would be safe to operate these rectifiers at maximum currents as high as 2 amperes.

The number of cells in the rectifier was determined by testing the circuit with different numbers of cells and

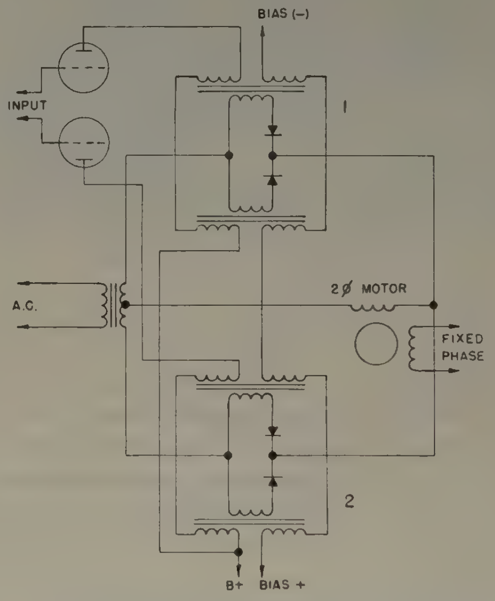

Figure 3. The self-saturating magnetic amplifier which was chosen for controlling the motor

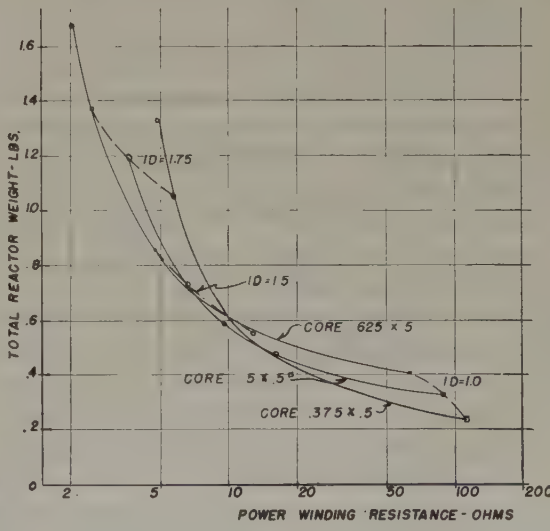

Figure 4. Reactor design curves. Total reactor weight includes weight of copper and iron

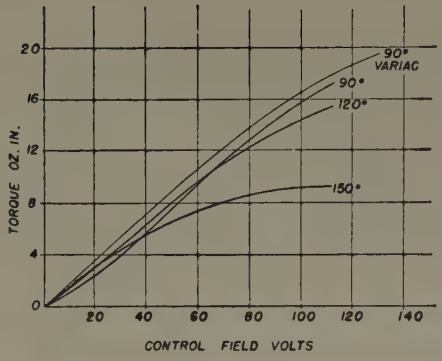

Figure 5. Stall characteristics of the motor with the magnetic amplifier supplying power to the control field for various values of phase shift of the fixed field

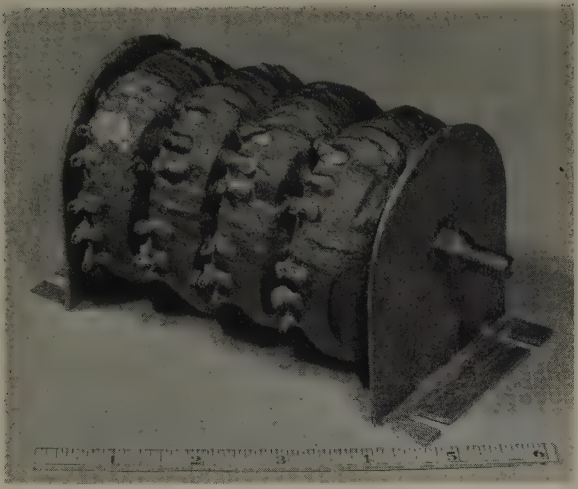

Figure 6. The Fosterite-treated reactor unit

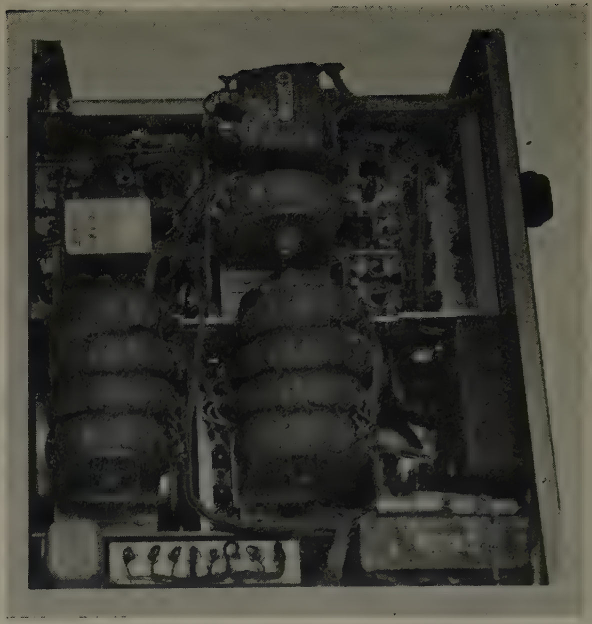

Figure 7. Two magnetic amplifiers on a chassis. The rectifiers are installed at the right

measuring the back voltage. Three cells chosen for the rectifier by these tests have 10 volts per cell peak inverse voltage. This low value of inverse voltage permits the circuit to operate with little change in characteristics over a wide temperature range. All the rectifiers required were made into a single stack $2^1/_4$ inches in diameter by $3^1/_2$ inches long.

TESTS ON THE MOTOR CONTROL

Since a magnetic amplifier shifts the phase of the voltage applied to the control field as well as changing its amplitude, it was thought that the motor torque might be a nonlinear function of the control voltage. The curves of Figure 5 show the magnitude of this effect.

The curve labeled 90-degree-variac was obtained by varying the control phase voltage with a variac so that a pure sine wave was applied. The fixed phase was operated at rated voltage shifted 90 degrees with respect to the control phase by means of a Scott transformer connection to the 3-phase supply. The other curves were obtained with the fixed phase shifted the indicated number of degrees from the voltage applied to the magnetic amplifier by various transformer connections to the 3-phase line.

The torque obtained with magnetic amplifier control is always somewhat less than that obtained with the variac, probably because of distorted waveshape. The maximum torque was greatly reduced for phase shifts other than 90 degrees, but the torque at low control field voltages was somewhat increased at phase shifts greater than 90 degrees because this partially corrected for the phase shift of the magnetic amplifier at low outputs. A 90-degree shift was used in the final design.

CONSTRUCTION OF THE REACTOR UNIT

Toroidal reactors were chosen because they generally weigh about one-third less than an equivalent stacked lamination reactor. These reactors have cores of Hypernik V square loop core material sealed in nylon boxes to protect them from mechanical strain. The natural and most evident solution for mounting the toroids was to stack them up on a post like doughnuts as in Figure 6. The aluminum rod must be insulated from the aluminum end plates by a bushing to prevent the formation of a short-circuited turn when the unit is mounted on a metal chassis. The terminals for each reactor are fastened to a strip of fiber which is tied to the reactor with thermal-setting pressure-sensitive tape. The connections between the reactors are all made externally. The reactor unit is Fosterite-treated to improve the heat transfer, protect the windings from humidity, and give the unit mechanical strength. Hermetically sealing the unit in a can would be just as good but would be considerably heavier. A ring of Fiberglas insulating material about 1/4 inch thick is stacked between the reactors to fill the voids between the reactors so that a continuous cup of the thick Fosterite material can be formed.

In over a year of servo testing there have been no failures of either the reactors or the rectifiers. The motor control amplifier is now considered to be a completed development. The space saving possibilities of this method of motor control can be seen in Figure 7 where two of these control amplifiers are mounted in the chassis of a piece of air-borne equipment.

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1. Magnetic Amplifiers, **S. E. Tweedy.** *Electronic Engineering* (London, England), volume 20, March 1948, pages 84–8.

International Sales Through Investment

I. F. BAKER
MEMBER AIEE

In this stage of our national history, when the United States increasingly must identify its own growth with that of the world as a whole, there are three things which we can contribute to world economy: our products, our dollars, and, most important, our technical knowledge.

THE SUBJECT of this article may seem like something of a paradox, since generally we tend to think selling abroad is one thing and investing abroad is another. To many exporters, however, the connection is clear enough. Unlike the domestic trader, the exporter does not find himself in one big market that stretches from Maine to California. Instead he finds himself confronted with dozens of smaller markets, each with its own buying habits and restrictions on imports, investments, export of goods, and exports of profits.

In trying to cut through the barriers to selling abroad, the manufacturing exporter may be faced with a decision of opening a branch plant on the other side of the barrier. This he finds to be far more complicated than would be the problem of an eastern manufacturer who decides to open a branch in the South, for in such a case his profits would not be halted at the state line, nor would he be faced with a production crisis because he could not get raw materials for his plant from one state to another. That is typical of what happens to the foreign investor, however, whether he is considering opening up a branch abroad or merely investing in a going local concern.

Naturally no investor is going through the red tape of investing abroad unless he has a strong incentive. It would be unrealistic not to say that at present private foreign investment is still a stepchild. Nevertheless, increased foreign investment is vital not only to the nation but to businessmen themselves. When such a necessity exists, there is little doubt that sooner or later the people of the United States will find a way to overcome the obstacles to investments which exist within our borders, and will help the people of other friendly countries to overcome the obstacles which exist abroad.

BASIC CONSIDERATIONS

ONE OF THE REASONS our system works as well as it does is that we can develop, produce, and sell in terms of a mass market. Sometimes the home market seems so enormous that there appears to be little reason to bother about sales abroad. But when things start to tighten at home, the sales that the export sales manager or the head of the international division of a company can report are extremely welcome.

Unfortunately, the foreign market may not always be there when you want it. During the Economic Cooperation Administration period, Western Europe and the Mediterranean region offered many opportunities to the foreign trader. I have had a chance to observe the shrinking of this market during the past year, when my travels have taken me twice to France and Italy and once to Spain, Greece, and Egypt. I can clarify the present picture by saying that it reminds me of the 1930's when I lived in London and was able to watch the local situation closely. All the countries I visited more recently have increased their power and industrial facilities considerably and consequently have broadened their product demands. Not only are the Marshall Plan funds now exhausted, but strong, experienced foreign competitors are going after the dollar business which once was safely in our pockets.

In Latin America the same factors are at work. After all, these areas are in many respects more European than is North America; not only is their language European, but there is much cultural contact with the original Romance countries—Spain, Italy, Portugal, and France. Travel time by airplane is only a few hours longer from Rio de Janeiro to Paris than from Rio de Janeiro to New York. The Napoleonic Code prevails in legal practice and the metric system is in effect.

Fortunately, the industrial products which have been produced for our own use are also highly suitable to the present development needs of Latin America. The result is that transport is filled with engineers and businessmen of both continents engaged in the production and exchange of oil from Venezuela, copper from Chile, wheat from Argentina, and manufactured products from the United States.

All this activity is a sign that the pace of development in Latin America, as elsewhere, is speeding up, and that a new stage of industrial expansion is under way despite the limitations of exchange and material shortages. The first great stage of Latin American development was largely a European affair, with the British in the forefront. Originally much British capital was invested in railways, textiles, and mining. For example, $100 million was invested in the Anglo-Argentine tramways of Buenos Aires, while more than 15,000 miles of extra-broad-gauge railways were built in Argentina between 1870 and 1914, for a total investment exceeding a billion dollars.

By the outbreak of World War I European investments in Argentina alone had reached $3.9 billion and were divided as follows: Britain, 65 per cent; France, 13 per cent; Belgium and Italy, 7 per cent; and other countries, 15 per cent. Likewise in Brazil, the British built 2,000 miles of railways, while the Canadian-British power enterprise,

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Essentially full text of a talk before the Export Managers' Club, New York, N. Y., March 4, 1952.

I. F. Baker is Vice-President and Treasurer, Westinghouse Electric International Company, New York, N. Y.

the Brazilian Traction Company, built the power plants which made possible the great development of Rio de Janeiro and São Paulo as residential, commercial, and industrial centers. British investments in Brazil reached 275 million pounds sterling at the high-water mark of 1921. Thus for half a century a foundation of public services was being developed by the British, with considerable assistance from the French, Americans, and Belgians. The railway, gas, light, power, and water facilities that came into being during this period are the basis for the present standard of living and the present possibilities for foreign trade.

In taking a backward glance at the first great surge of development in South America, we might draw an analogy with the history of the United States when it, too, was an "underdeveloped" area. From this history, we find that the development of a country seldom follows a smooth pattern; rather, it surges ahead for a period until it is found that the available resources have been overstrained. Then a reaction appears in which development suffers while more "capital energy" is stored up.

We also might draw another lesson from early United States history with regard to the difficulty of securing foreign exchange. Exchange always has been a precious thing to a growing country, whether it be the United States, the growing industrial giant of the 19th century, or one of the new industrial countries of Latin America. Every dollar sent out for services, goods, or dividends means sacrifice elsewhere. It is not the earnings but the remittances that cause financial strain.

During the last century the United States also had difficulty at times in securing foreign exchange. This led to both government and private borrowing from abroad, coupled with a great volume of equity investments from Europe. As industry and agriculture progressed, the United States not only acquired export balances but paid off most of its foreign debts and achieved balances which exceeded the equities of the invested capital. The countries which had invested in shares here often profited greatly and in many cases still profit from holdings, most of which were acquired at a more prosperous period in their history.

Even though a 20th-century American is not used to thinking in such terms, it well may be that the United States again will need large amounts of foreign exchange. It may not be long before sulphur, magnesium, lead, copper, zinc, and timber will have to come from abroad as do manganese, tin, bauxite, and tungsten at the present time. The United States is steadily becoming an importing nation. We can see that trend operating in some of the most basic materials. Our domestic oil industry is a giant enterprise, but it has been forced to spread over to Saudi Arabia and Venezuela. Our iron mining industry is also a giant enterprise, but it, too, has been forced to explore new sources of iron ore and is now in the process of developing new mining regions in Venezuela and Labrador. It is fortunate for all of us that this process is possible, or the fountainhead of our national success would dry up and we would find ourselves reduced to the status of a "has-been" nation.

We are now at a very critical stage of our national history in the industrial as well as the political sense. That is the disturbing factor in the attempts of some to minimize the importance of a steady flow of either public or private capital abroad. Not only is it unpopular to enforce sanctions on foreign investment, but it would interrupt the growth of the world economy at a time when our own expansion is bringing us to rely on this growth both to supply us with materials and to develop new markets for our products.

THE SITUATION TODAY

The factors discussed thus far have been important in the past or may be important in the somewhat distant future. The past and the distant future are important as indicators, but the vital question is the nature of the situation that confronts the investor now and in the immediate future, during what is likely to constitute the third stage of Latin American development.

Financially, one of the first factors which strikes the attention is the heavy pressure placed on local banks, insurance companies, and private sources for development funds. The result is that it is quite common to pay 12 per cent on real estate loans, and the range is between 9 to 20 per cent or even higher. Such a high yield was not at first favorable to local investment in manufacturing facilities, but the strong demand for goods which could not be obtained from abroad because of production or exchange difficulties has created some very profitable investment situations.

In terms of sectors of industry, there are four great classes which all demand considerable expansion before Latin America can approach the standard of living of the United States. These are: railroads, utilities, manufacturing industries, and oil and mining. Of these four groups, government participation will be required in the first two, railroads and utilities, if private enterprise is to find the remaining groups, manufacturing and oil and mining, favorable for large-scale development.

The entire rate of progress of Latin America hinges on the speed with which its power supply and its transportation facilities are expanded. To sell a radio or a motor-driven machine abroad, you need power. At the very threshold of a country adequate port facilities are needed, and there must be an adequate means of transporting both men and goods from one place to another within the country to make possible both production and sales. These elementary considerations also must be passed in review by the foreign investor and his local collaborators.

For a closer view of the investment situation in Latin America, let us consider one country, Brazil, which offers the most interesting all-around prospects for the foreign investor anywhere on the continent.

Following the first great surge of investment in Brazil which ended with the first World War, there came a second influx of capital, largely from North America. This, likewise, was interrupted by World War II, but following a decree in 1946 which favored repatriation of capital and allowed exchange for an 8 per cent dividend, there has been a third inflow of private capital which included both European and American investors. As of December 1949, the original investment of these firms was $315 million but this has been augmented by investment of surplus Brazilian earnings to reach a total capital of $830 million. In addition to this, there has been an enormous development of manufacturing with Brazilian capital, and an apparent excess of demand over supply has produced good profits and caused an exceptional demand for raw materials and many other important items. The net result is that Brazil finds herself with an active manufacturing industry which is growing steadily, and demanding for manufacture more and more electric power, oil, gas, transportation, port facilities, essential raw materials, and parts, with a circulating money supply equivalent to only $2 billion, and a yearly federal budget equivalent to $1,100,000,000, or less than the annual budget of the City of New York.

A statistical report from Rio de Janeiro gives a clear picture of the investment situation as reflected in earnings during 1950, the latest period reported. Net profit before dividends of 4,206 national companies for that year was 21 per cent. This compares with a 30 per cent profit of 146 foreign companies and $25^1/_2$ per cent profit for 168 companies of mixed local and foreign capital. The average dividend for all types of enterprises was only about 8 per cent, which means that these 4,520 companies with a capital equivalent of $\$2^3/_4$ billion put back into the business $400 million out of total earnings of $675 million.

Electric power companies showed 17.4 per cent earnings in capital of $277 million, or 9.3 per cent on capital and reserves of $520 million. However, with about the same capital and reserve, textile companies showed 50 per cent more profit in 1950. The paper, ceramic, and chemical industries were even more profitable while electric machinery, tobacco, steel, and banking were better than electric power but not so profitable as textiles. Tramway companies and railways are generally unprofitable. The depressed state for these enterprises carries over to other countries as well as Brazil.

Some of the crosscurrents which occur in the foreign investment situation are well illustrated by Brazil. Including dollar earnings of 800 million on coffee, the total exports from Brazil last year equalled an earlier estimate of one billion dollars. However, the healthy demand for dollars which arose for imports of 100,000 barrels of oil daily, plus automotive equipment, machinery, wheat, and materials for manufacture, exceeded expectations. Likewise, foreign earnings on investments had been unusually large, to such an extent that until recently the country was losing exchange at the rate of some $50 million a month. Some action had to be taken; hence, at the end of last year, President Vargas issued a decree limiting the exchange for dividends passing out of the country to 8 per cent of the original invested capital. Also, this invested capital was reduced by any previous remittance made in excess of the 8 per cent now authorized.

It is obvious that such a step can immediately dampen a foreign investor's enthusiasm. The ruling is especially harsh on the firms which already have a large stake in the future of Brazil. The situation needs to be cleared up both for the sake of present and future investors and for the sake of Brazil itself which stands to gain so much by making it possible for outside capital to go to work. Not only United States investors, but also British, French, and other nationalities, are interested in the opportunities in Brazil. One very hopeful sign has been the success of the local subsidiary of American and Foreign Power Company in marketing shares to Brazilian investors. It is important not only to tap new sources of financing but also to protect the existing investment.

The situation of Argentina presents an even more complicated picture of favorable and unfavorable trends. Here lack of information regarding future developments raises many questions in the minds of prospective investors. There are a number of economic factors to consider, such as the recent drought, the power shortage, price control and inflation of wages, and the resultant need to cut back on imports. Despite this combination of long- and short-term trends, Argentina remains a vigorous country. It would be unprofitable to sell the country short. It is to Argentina's own advantage to encourage outside investment because property is not indestructible; if it is to be valuable it requires constant attention and improvement. Only additional investment can protect facilities which already exist.

THE PROBLEM

THUS FAR, this article has tried to provide an idea of the opportunities which have arisen abroad, with special reference to Latin America; but where it mentioned the high returns on industry in Brazil, little was said about getting those returns out of the country. We may very well wish to plough back a fairly large proportion of our earnings into expansion of our foreign enterprise, but if we do we would prefer the choice to be ours, not that of the government of the country in which our capital is invested. Unfortunately, that is the crux of the whole problem of increased United States investments abroad. Somehow we must see to it that there is sufficient return on investment to make such investments attractive to private enterprise, whether represented by manufacturing concerns, or banks, or small investors. There has been such a continual hue and cry about the need for favorable general investment conditions that this matter need not be explored further here. Instead, a few possibilities for solving the problem will be considered.

Actually, in spite of the decrease in investment, much money is going abroad to stimulate the extraction of oil and certain other mineral products which are necessities. This is a form of investment which provides its own exchange for dividends and which is justly popular at home and abroad. Furthermore, American money continues to flow into Canada, not only because of the tremendous industrial potentialities of the country, but even more because Canada represents a working model of the kind of investment situation which we would like to see elsewhere. United States money is going into Canada because there is every assurance that a fair return on this money will be coming out without being halted at the border.

The barriers to foreign investment do not all originate abroad. One of the chief difficulties lies in the tax barrier set up by our own government. An indication as to what lengths private investors are forced to go to put their funds to work is the emergence of what in the trade are called "Panamanian" companies. These are companies registered in Panama which have the function of accumulating earnings. If dividends can be repatriated without confiscatory taxes, such a company may remain in existence for some time. If it is decided to sell the company, a captial gains tax is paid.

Such an arrangement may represent a rather ingenious method of carrying on business in the face of discouraging circumstances, but, still more, it is a sign that something must be done to make foreign investment a part of the normal activities of the nation rather than an occasion for exercising ingenuity.

Foreign investment by private enterprise has been given official recognition by the United States government as an essential element in the role which our country is playing in the world. That recognition was given with the announcement of the Point Four program. What has been accomplished since that announcement is another matter.

The fact is that in more ways than we realize, we operate under a government of checks and balances. In the case of foreign investment, the checks have been interfering with the balances.

On the one hand, it is admitted that increased foreign investment is a necessity, and on the other hand, the tax structure under which the foreign investor must make his decisions remains too unfavorable to encourage him to strong action. It is true that the government has arranged commercial treaties with a number of countries governing the basic rules of conduct of these countries toward foreign investment and that many other countries will sign similar agreements. It is also true that Mutual Security Agency offers investors a guarantee that reasonable profits may be returned from the Marshall Plan countries. But the silence with which investors have greeted these desirable and well-intentioned measures is an indication that the government has not found the solution to the problem.

We must not look only to the legal restrictions of other countries but also must scrutinize our own tax structures. The present tax law treats the income from a Point Four venture abroad with the same rules as a gilt-edged investment at home. There is no provision for a 75 per cent write-off during a 5-year period of favorable conditions. Nor is there any tax exemption to put the investor on a competitive basis with institutions which have no obligation for income tax and which therefore can loan at low rates. Our government should consider not only the possibility of decreased tax rates, but of government loans at moderate rates to foreign enterprise. Meanwhile, we also should be alert to the possibility of legislative relief by the various foreign governments. However, it scarcely can be expected that foreign exchange can be made available in sufficient quantities not only to give an attractive net yield to the American investor, but to pay taxes which are about double this net yield. Even if Brazil doubled the maximum rate of dividend which could be converted into dollars, this 16 per cent would yield only 3 per cent at the top bracket assessment of 82 per cent which often must be applied to new and additional undertakings.

We in the United States have a number of things which we should be using more freely throughout the world. We have our products; we have our dollars for investment; and we have industrial know-how, which is often more precious than our products and our dollars. If you do not care to make a large permanent commitment of funds abroad, remember that the man who offers his know-how is also an investor. He still can make use of license agreements to combine engineering and marketing ideas from the United States with local capital and local manpower. In many cases he may need to back up this effort a little further by supplying not only engineers and sales specialists but materials and component parts to insure the practical success of the licensee company.

Those primarily interested in sales may find that there are many ways in which license arrangements will build a basis for export sales. There are some cases in which a heavy foreign tax on royalties need not rule out the arrangement of a license agreement because there is still the possibility of profits on the sale of materials.

In short, there are many ways in which our talents for designing, producing, selling, and taking risks can be turned to both individual profit and national and international advantage. We must not let restrictions cause us to refuse to consider investment. They should only add to our efforts to create the healthy atmosphere necessary for greater foreign investment. When the transfer of our goods, our money, and our know-how is of advantage to the United States, and to the business and industry which form so great a part of the strength of our country, we should make sure that the rules of government and the activities of private enterprise work together toward the same goal.

Drop-Frame Car Ships Transformers

The long railroad car pictured above was specially designed by the New York Central Railroad to ship large power transformers built by the General Electric Company, Schenectady, N. Y. The drop-frame construction of the car was designed to make clearance possible through the railroad tunnels and under low bridges. The car is 67$^1/_2$ feet long, weighs 160,000 pounds, and has 16 wheels supporting a 25-foot platform

INSTITUTE ACTIVITIES

Minneapolis, 1952 Summer Meeting Site, Offers Many Recreational Opportunities

Minneapolis, Minn., site of the 1952 AIEE Summer General Meeting, June 23–27, is considered the industrial and mercantile gateway to the Upper Midwest. With its twin city, St. Paul, it forms a metropolitan community of 900,000 persons that manufactures, stores, and distributes much of the goods for the extensive agricultural area lying to the north and west, and receives and processes the cereal products for that area.

The Twin Cities are accessible to more than a dozen vacation regions encompassing thousands of clear water lakes abounding in native game fish. The resort business is an important industry in Minnesota.

INDUSTY IN THE TWIN CITIES

The industrial beginnings of Minneapolis centered around St. Anthony Falls in the Mississippi River, where a natural head of water furnished power which brought flour mills to the shores. As the mills grew, electric power replaced hydraulic, yet today many of the large mills are located at the falls. The presence of these waterfalls also led to the establishment of a hydroelectric generating station at their site in 1882.

Twenty years later the AIEE Minnesota Section was formed here, and now, 50 years later, the Summer General Meeting will commemorate its founding. A historical display pertaining to the electrical industry and to the Minnesota Section is to be seen at this meeting.

Minneapolis today has more than 1,000 manufacturing plants. Numbered among these are Electric Machinery Manufacturing Company, Control Corporation, Minneapolis-Honeywell Regulator Company, D. W. Onan and Sons, Maico, and other electrical firms. St. Paul likewise has such electrical manufacturers as Telex, Microtone, Engineering Research Associates, and Minnesota Mining and Manufacturing Company. The products of these firms range from hearing aids and electric controls to heavy rotating machinery and large-scale digital computers. Inspection trips have been arranged to several of these plants.

There are also more than 1,500 wholesale distributors with an annual volume of 2.5 billion dollars situated in Minneapolis. Among them are regional branches of General Electric Company, Westinghouse Electric Corporation, United States Steel Corporation, and Graybar.

Electricity for these industries and for domestic users comes from stations of the Northern States Power Company. This company's transmission system extends from South Dakota into Wisconsin, and connects a generating capacity of 800,000 kw. The largest single source is the Riverside Steam Plant in Minneapolis, with capacity of 262,000 kw in seven turbogenerator units. An inspection trip through this station has been scheduled. Another inspection trip will visit a hydroelectric station on the system which was installed at Taylor's Falls the same year that the Minnesota Section was established.

THE INDIAN LEGEND

Besides being known for its milling, Minneapolis has been immortalized by Henry Wadsworth Longfellow through the poem, "Hiawatha." The Falls of Minnehaha (Laughing Water), after which his heroine was named, are located within the city limits. A tour available will include a visit to the falls and a ride along Minnehaha Creek as it flows through Lake Nokomis and Lake Hiawatha, thence over Minnehaha Falls and into the Mississippi. All these waters are within the municipal park system, as are several other lakes that may be visited.

FEATURES OF THE MEETING

Daily luncheons are being held at the headquarters hotel the week of the meeting. James Lewis Morrill, President of the University of Minnesota, will welcome the members at the opening. Another na-

Future AIEE Meetings

North Eastern District Meeting
Arlington Hotel, Binghamton, N. Y.
April 30–May 2, 1952
(Final date for submitting papers—closed)

AIEE Textile Conference (South)
Georgia Institute of Technology, Atlanta, Ga.
May 1–2, 1952

Joint AIEE-IRE-RTMA Conference on Progress in Quality of Electronic Components
Roger Smith Hotel, Washington, D. C.
May 5–7, 1952

AIEE Conference on Domestic Appliances
Engineering Society's Building, Cincinnati, Ohio
May 16–17, 1952

AIEE Conference on Electronic Converter Applications and Tubes *(page 474)*
William Penn Hotel, Pittsburgh, Pa.
May 19–20, 1952

Summer General Meeting *(page 473)*
Hotel Nicollet, Minneapolis, Minn.
June 23–27, 1952
(Final date for submitting papers—closed)

Pacific General Meeting
Hotel Westward Ho, Phoenix, Ariz.
August 19–22, 1952
(Final date for submitting papers—May 21)

AIEE Participation in Centennial of Engineering
Congress Hotel, Chicago, Ill.
September 10–12, 1952
(Final date for submitting papers—June 10)

Fall General Meeting
Jung Hotel, New Orleans, La.
October 13–17, 1952
(Final date for submitting papers—June 13)

Middle Eastern District Meeting
Commodore Perry Hotel, Toledo, Ohio
October 28–30, 1952
(Final date for submitting papers—July 30)

General Mills Plant beside St. Anthony Falls in Minneapolis, to be visited during the 1952 Summer General Meeting

tionally prominent speaker will address a mid-week luncheon group.

Following the annual meeting on Monday morning, June 23, there will be $4^{1}/_{2}$ days devoted to 44 technical sessions. Sessions on Sections' policy and business will occupy Tuesday, and student activities are on the program for Wednesday. Ladies' activities have been scheduled to parallel all the technical sessions.

SOCIAL AND RECREATIONAL EVENTS

A golf tournament has been arranged for Tuesday, June 24, at the University Golf Course for those who enjoy this game. Five prizes will be awarded for low gross and net scores, with handicaps determined by the Peoria system. Courtesy cards for various other courses will be available from the Sports Committee throughout the week.

A sailboat race between the different AIEE Districts will be run Wednesday evening, June 25, on Lake Calhoun in Minneapolis. The race is over a 3-mile triangular course, with trophies for win, place, and show. District Vice-Presidents are expected to be aboard their entries. A large park surrounding the lake permits unobstructed viewing of the course.

On Thursday evening a dinner-dance will be held at the Nicollet Hotel.

Fly casters and bait casters are invited to participate in the AIEE Fishing Contest. Prizes will be awarded for the largest fish caught during the week (and weighed by somebody else). Entry blanks will be available upon registration and must be returned in time for winners to be announced at the luncheon Friday noon.

ACCOMMODATIONS

Early room reservations are urged. Those who plan to drive or stay at motels or nearby resorts may obtain information by writing the Tourist Information Bureau, Minneapolis Chamber of Commerce, 1750 Hennepin Avenue, Minneapolis 3, Minn. Specific resort information will be available at the meeting headquarters.

Hotel rooms may be reserved by writing directly to the Nicollet Hotel, Minneapolis, Minn., or the hotel preferred, and stating that the reservation is for the AIEE Summer General Meeting. Hotel rates were given in the April issue, page 381.

TRIP TO THE IRON RANGE

Under the auspices of the AIEE Arrowhead Section, an extended inspection trip to Duluth and the Mesabi Iron Range will be available during the latter part of the week of the meeting. Detailed information regarding this trip, which can be made by private car or public transportation, will be made available during the meeting.

Duluth, with a shipping tonnage second only to New York, is the shipping point for grain and iron ore and the receiving point for coal carrying vessels. Its manufacturing industry is diversified and some of its factories will be open to AIEE members and guests who make the tour. The Minnesota Power and Light Company will open a steam and a hydroelectric plant for inspection. A 30-mile, picturesque drive along Lake Superior is recommended to those who visit Duluth.

At the Mesabi Iron Range, about 60 miles from Duluth, five open pit and underground iron mines and five ore processing plants (three in operation and two under construction) may be visited. A new steam-powered generating station under construction in this area will be seen also. A complete tour of these facilities can be made to include a scenic drive through wilderness country on good roads without retracing any of the route.

Electronic Converter Conference Planned for Pittsburgh in May

The AIEE Joint Conference on Electronic Converter Applications and Tubes will be held in the Monongahela Room of the Hotel William Penn, Pittsburgh, Pa., on May 19–20, 1952. This conference, the third in a series relating to electron tubes, is to be sponsored jointly by the AIEE Committee on Electronic Power Converters and the Subcommittee on Electron Tubes of the AIEE Committee on Electronics.

Special features of the coming conference will include: inspection trips to rectifier manufacturing facilities and to rectifier installations; a panel discussion of power rectifying devices treating pool-type tanks and tubes, metallic rectifiers, and mechanical rectifiers; and a conference session on application requirements and user practices in the electrochemical, transportation, mining, and general industry fields.

The committee report on "Survey of Operation of Mercury Arc Rectifiers" will be presented at the final session. Copies of this report will be available at the con-

Technical Program

Joint Conference on Electronic Converter Applications and Tubes Pittsburgh, Pa., May 19-20, 1952

Monday, May 19

9:30 a.m.

Welcome: W. A. Albert, Chairman, Pittsburgh Section Conference Committee; West Penn Power Company, Pittsburgh, Pa.

9:30 a.m. Session 1, Opening Session

Presiding: W. A. Albert

Purpose of Conference. *C. C. Herskind*, Cochairman; General Electric Company, Schenectady, N. Y.

Field of Rectifier Applications. *H. Winograd*, Cochairman; Allis-Chalmers Manufacturing Company, Milwaukee, Wis.

General Theory and Basic Principles. *C. R. Marcum*, Westinghouse Electric Corporation, East Pittsburgh, Pa.

Rectifier Standardization. *L. W. Morton*, General Electric Company, Schenectady, N. Y.

1:00 p.m. Inspection Trips

Trip A: Westinghouse Electric Corporation plant at East Pittsburgh, including rectifier manufacturing facilities

Trip B: 20,000-kw frequency-changer installation at Edgar Thomson Works, United States Steel Corporation, and steel making and rolling operations at Homestead Works, United States Steel Corporation

(Note: Trips A and B require United States or Canadian citizenship)

Trip C: Rectifier installation for coal mining service (Note: This trip will be arranged if there is sufficient interest)

8:00 p.m. Session 2, Panel Discussion of Power Rectifying Devices

Presiding: Dr. C. H. Willis, Princeton University, Princeton, N. J.

Ignitrons. *A. Schmidt, Jr.*, General Electric Company, Schenectady, N. Y.

Excitrons. *H. Winograd*, Allis-Chalmers Manufacturing Company, Milwaukee, Wis.

Hot Cathode Tubes. *H. C. Steiner*, General Electric Company, Schenectady, N. Y.

Metallic Rectifiers. *I. R. Smith*, Westinghouse Electric Corporation, Buffalo, N. Y.

Mechanical Rectifiers. *Otto Jensen*, I-T-E Circuit Breaker Company, Philadelphia, Pa.

Glass Tubes and European Manufacture. *J. T. Thwaites*, Canadian Westinghouse Company, Ltd., Hamilton, Ontario, Canada

Tuesday, May 20

9:30 a.m. Session 3, Application and Practice

Presiding: R. N. Wagner, Aluminum Company of America, Pittsburgh, Pa.

Application Requirements for Rectifiers

- **Electrochemical Service.** *F. L. Kaestle*, General Electric Company, Schenectady, N. Y.
- **Transportation Service.** *D. W. Borst*, General Electric Company, Schenectady, N. Y.
- **Mining Service.** *J. E. Robles*, Westinghouse Electric Corporation, Pittsburgh, Pa.
- **General Industry.** *W. E. Gutzwiller*, Allis-Chalmers Manufacturing Company, Milwaukee, Wis.

Maintenance and Operating Practices

- **Electrochemical.** *Waldo Porter*, Aluminum Company of America, Vancouver, Wash.
- **Electrochemical.** *E. H. Coxe*, Ethyl Corporation, Baton Rouge, La.
- **Transportation.** *J. Y. Doran*, Toronto Transportation Commission, Toronto, Ontario, Canada
- **Mining.** *R. J. Nix*, Rochester and Pittsburgh Coal Company, Indiana, Pa.
- **General Industry.** *A. D. Howry*, Allan Wood Steel Company, Conshohocken, Pa.

2:00 p.m. Session 4, Operation and Maintenance

Presiding: C. C. Herskind, General Electric Company, Schenectady, N. Y.

Survey of Rectifier Operation. *R. M. Hunter*, Rochester and Pittsburgh Coal Company, Indiana, Pa.

Rectifier Cooling and Corrosion Problems. *E. J. Remscheid*, General Electric Company, Schenectady, N. Y.

Guidance Aids for Rectifier Users. *W. R. Kettenring, Jr.*, General Electric Company, Schenectady, N. Y.

Tube Life. *M. M. Morack*, General Electric Company, Schenectady, N. Y.; *D. E. Marshall*, Westinghouse Electric Corporation, Bloomfield, N. J.

ference. The other papers listed on the program will not be available in printed form at the time of the conference, but will be published later in the conference *Proceedings.*

HOTEL RESERVATIONS

The Hotel William Penn is centrally located to all forms of transportation. Limousine service to and from the airport is provided at the hotel. Rooms have been allotted for those attending the conference and reservations may be obtained directly from the hotel.

CONFERENCE REGISTRATION

The registration desk will be located on the 17th floor of the Hotel William Penn near the Monongahela Room and will be open at 8:30 a.m. Registration for the conference will be $3 and will include all sessions.

COMMITTEE MEMBERS

The chairmen of the committees arranging the conference are: C. C. Herskind and H. Winograd, Conference Cochairmen; W. A. Albert, Pittsburgh Section Conference Chairman; A. A. Johnson, Pittsburgh Section Chairman; W. J. Lyman, Pittsburgh Section Secretary-Treasurer; C. R. Marcum, Program Chairman; J. L. Boyer and A. P. Colaiaco, Publicity Chairmen; D. E. Marshall, Publication Chairman; I. K. Dortort, Scott Helt, and J. J. Thwaites, Sponsoring Committee Chairmen.

Hoover, Edison Featured Speakers at Dinner Honoring Lee de Forest

On April 8, 1952, Dr. Lee de Forest was honored by a dinner at the Waldorf-Astoria Hotel celebrating the 50th anniversary of his entry into commercial wireless telegraphy, as the art was then known. The event also commemorated the 45th anniversary of the birth of the 3-element tube, or "audion." One of the most far-reaching inventions of this century, this tube is used in every broadcast and television transmitter and receiver, in telecommunications by wire and radio, in electronic devices of every kind, including radar and guided missiles, and in every motion picture theatre. Dr. de Forest, the "Father of Radio," is now 79.

Featured speakers at the dinner were former President Herbert Hoover and Charles A. Edison. Mr. Hoover, like Dr. de Forest, is a native son of Iowa and an adopted son of California. When Secretary of Commerce, he played a leading role in government regulation of radiobroadcasting. Mr. Edison, formerly a governor of New Jersey, was Secretary of the Navy at the outbreak of World War II. His father, inventor Thomas A. Edison, was responsible for the "Edison effect" which formed the basis of Dr. de Forest's 3-element vacuum tube.

Mr. Hoover, in his remarks, ranked Dr. de Forest with four others; Michael Faraday, Thomas Edison, Samuel Morse, and Alexander Graham Bell; as the most important inventors of the last 150 years. He pointed out that these men are outstanding because their work has affected the living habits of all mankind, and he showed some of the parallels in their lives.

Mr. Hoover agreed that the most revolutionary of the De Forest inventions was the electron tube from which has come, among other innovations, radio, television, and radar. "I can imagine," he said, "that if Dr. de Forest had shown his contraption of the electron tube to an American political leader he would have been asked the same question as had been put to Faraday (that is, 'What practical use is it?'). I can imagine de Forest replying, 'Sir, some day you will try to regulate it with laws.'" Today, of course, regulation is the bane of the industry.

The speaker acknowledged that though Dr. de Forest has brought many blessings to mankind through radio, he has some grave matters to answer for since he also has made it possible to transmit bad music, political speeches, and singing commercials. "But Dr. de Forest could redeem himself," Mr. Hoover went on, "if he would produce another great invention. That is the push button by which we could transmit our emotions instantly back to the broadcasters. It would explode our feelings over the air instead of having their inner gnawing of our morals."

Others at the speakers' table included Brigadier General David Sarnoff, Chairman of the Board of the Radio Corporation of America, one of the largest users of the De Forest invention; Colonel Sosthenes Behn, Chairman of International Telephone and Telegraph Corporation; Walter Marshall, President of Western Union; Dr. Mervin J. Kelly, President of Bell Telephone Laboratories; and Rear Admiral Stanford C. Hooper, United States Navy (retired), "Father of Radio" in the Navy. Rear Admiral Ellery W. Stone, President of American Cable and Radio Corporation and an associate of Dr. de Forest in 1920, presided at the dinner.

On behalf of The De Forest Pioneers, the organization's president, Elmo N. Pickerill, presented a bronze bust of Lee de Forest to Yale University, from which Dr. de Forest was graduated with the class of 1896. The bust, the work of Frederick Allen Williams of New York, was received on behalf of the University by Irving S. Olds, Chairman of the United States Steel Corporation and a Fellow of the Yale Corporation.

Lee de Forest

The dinner was sponsored by The De Forest Pioneers with seven other organizations: AIEE, the American Radio Relay League, the Institute of Radio Engineers, National Association of Radio and Television Broadcasters, Radio-Television Manufacturers Association, Society of Motion Picture and Television Engineers, and Veteran Wireless Operators Association. In addition to Mr. Pickerill and Admiral Stone, prominent members of the Pioneers include Dr. Allen B. Du Mont, William Barkley, John V. L. Hogan, Frank Andrea, and Haraden Pratt, Telecommunications Advisor to President Truman.

Progress Reported in Work on Uniform Graphical Symbols

Graphical symbols for electrical engineering can be a shorthand that all electrical engineers, electrical technicians, and draftsmen can understand or they can be only a means of cramming a great deal of information into a small space on a given drawing. The latter case is true when every organization has its own symbols. Then an engineer cannot be sure when he reads a schematic that originated in another organization that he understands what each symbol means. In order to be sure, a legend must accompany every diagram stating for what each symbol stands.

Engineers in many organizations must draw and explain schematics for use in their own organizations, by their customers, and on contract, by other organizations and the Armed Services. Sometimes the contracting organization can persuade its customers to accept schematics and the corresponding instruction manuals with symbols which are unique to the contracting organization. In this case, the customer is forced to train its technicians in two symbol languages: first, the symbol language it uses normally; and second, the symbol language unique to the contracting organization.

In the long run, it seems logical that, in the best interests of all engineers, electrical technicians, draftsmen, the Armed Services, and all other organizations, there should be only one symbol language.

Can such a language be agreed upon? Great progress has been made in the past year in creating confidence among the workers in this field that a single language is attainable. In the first place, an American Standards Association task group has prepared a draft applicable to the fields of telecommunications, control engineering, and power engineering. There have been 12 meetings of the task group. The first meeting was on December 15, 1950; the most recent, on February 15, 1952. Each meeting lasted one day. At these meetings each representative of an organization made proposals or counterproposals prepared by the group he had formed in his own organization to discuss the progressive drafts as they were circulated.

In the second place, a representative from industry sat with the Munitions Board Standards Agency (MBSA) task group which group charged with reviewing *JAN-STD-15* and with preparing a draft of *MIL-STD-15A* to replace it. The first draft has been circulated for comments to members of the ASA task group as well as to the members of the MBSA task group. A representative from the Defense Department of Canada sat with the ASA task group during three of the more recent meetings.

In the third place, a United States expert (from United States industry) sat with the International Electrotechnical Commission (IEC) task group of experts authorized to review IEC Publication 35 (Power Symbols) and to prepare a draft of a new standard to replace it. It was agreed at this meeting that experts of the telecommunications industries should meet simultaneously with experts of the power industries to decide on mutually acceptable symbols. Some work on the new draft was accomplished at the 3-day Montreux meeting of the IEC task group in November 1951. The remainder is scheduled to be accomplished during a 3-day Paris meeting of the IEC task group which is to be held in May 1952.

Change for the sake of change is not necessarily an improvement; but the change that is adopted so that all can agree is progress. An engineer, by the nature of his training, tends to look at problems objectively, review all the facts, and then propose a solution that is likely to be acceptable, with a few amendments, to all concerned. It has been found by experience that conflicts in standards between strong groups in any one organization ordinarily cannot be resolved within that organization. However, when representatives of these groups meet in a task group with representatives of other organizations mutually satisfactory compromises usually can be evolved.

Pittsburgh Section Dinner Meeting

(Above) Eight members of the AIEE Pittsburgh Section were presented with Fellow Grade Certificates at the annual Vice-President's Dinner Meeting, January 14, 1952, by Vice-President J. C. Strasbourger. Recipients were, left to right: R. L. Witzke, H. G. Barnett, W. H. Osterle, L. L. Fountain, M. L. Gardner, W. E. Pakala, D. W. VerPlanck, also J. A. Hutcheson, who was absent. (Above) A father and son who are both Fellows of the AIEE were recognized by members of the Pittsburgh Section at the meeting. Vice-President Strasbourger and Chairman A. A. Johnson awarded H. N. Muller, Sr., and H. N. Muller, Jr., certificates honoring this distinctive professional attainment

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Annual dinner meeting of the AIEE Seattle Section, with the local engineers playing host to engineering students from the University of Washington. Shown speaking is Dean Wessman of the University's College of Engineering

Seattle Section Plays Host to Washington University Students

On March 4, 1952, the AIEE Seattle (Wash.) Section played host to the nearby University of Washington Student Branch at an annual "papers meeting." The dinner meeting took place at the Edmond Meany Hotel, with each engineer pairing off with an engineering student guest.

Highlighting the dinner hour were 3-minute talks by six past chairmen of the Seattle Section. Oldest past chairman present was Joseph Hellenthal, Puget Sound Power and Light Company, a University of Washington student in 1898, who gave vivid impressions of school days when the enrollment was just 300 (today it is 15,000) and the university was contained in just one building.

Section Chairman C. D. Howe, after opening the meeting, turned the program over to John Nelson, Assistant Superintendent, Lighting Department, City of Seattle. Dean H. E. Wessman of the University of Washington College of Engineering responded briefly.

Following the dinner, the Student Branch presided and seven technical papers were presented. First prize award went to Bruce Kieburtz for his discussion of a 4-channel cathode-ray oscilloscope. He will take part in the District competition. Second prize went to Neal Drummond;

third, Ron Meredith; and fourth, Paul Snyder. D. R. Naurtil, Clifford Roth, and Lyle Stokes also presented papers.

Canton Section Initiates Management Discussion Group

The first meeting of the AIEE Canton (Ohio) Section's newly formed Management Discussion Group was held on March 4, 1952, at the Ohio Power Company Lobby Auditorium in Canton. S. D. Day is the group's chairman.

Featured speakers of the evening were C. J. Beller, Superintendent of Electrical Operations and Engineering, Cleveland Electric Illuminating Company, and W. H. Chase, Assistant Vice-President of Operations for the Ohio Bell Telephone Company. Mr. Beller, who is chairman of the National Committee on Management, discussed the need and scope of management discussion groups, while Mr. Chase emphasized the need for 2-way communication between management and employees.

Harold Turner, Vice-President and General Manager of The Ohio Power Company, greeted the group, congratulated them on their undertaking, and outlined some of the problems of management. Also present to help the Canton Section launch this new service to its membership was District Vice-President J. C. Strasbourger. After the formal talks, the speakers answered questions by members of the group.

Lehigh Valley Section Holds Joint Meeting

Featuring a discussion of "The Military Aspects of the Helicopter," the AIEE Lehigh Valley Section met in Reading, Pa., on March 14, 1952. This meeting was held jointly with the Reading chapter of the Pennsylvania Society of Professional Engineers.

Speaker of the evening was Hugh Mulvey, Chief Design Engineer for the Paisecki Aircraft Corporation, who told some 125 AIEE members and professional engineers of the present and contemplated military uses of the helicopter. In this respect, he described the utilization of the helicopter in the rescue of fighter pilots shot down behind enemy lines. He also spoke of the employment of this type of aircraft in transportation of men and supplies to otherwise inaccessible parts of Korea, rescue operations during carrier landings and take-offs, and laying of communication lines. In the event of atomic bombing, Mr. Mulvey predicted the use of helicopters for evacuation of contaminated areas to minimize the radiation exposure of rescue workers.

Shown at the recent joint meeting of the AIEE Lehigh Valley Section and the Reading chapter of the Pennsylvania Society of Professional Engineers are, seated, M. F. Rosol (left), Gilbert Associates, Inc., and manager, AIEE Reading Division, and Hugh Mulvey, Paisecki Aircraft Corporation, the speaker. Standing are, left to right: D. A. Campbell, Pennsylvania Power and Light Company, and Vice-Chairman, AIEE Lehigh Valley Section; J. O. Leslie, Gilbert Associates, Inc., and Chairman, Lehigh Valley Section; Colonel T. D. McPhail, Indiantown Gap Military Reservation; A. B. Snavely, Hershey Chocolate Corporation, and Vice-Chairman, AIEE Lehigh Valley Section

COMMITTEE ACTIVITIES

Editor's Note: This department has been created for the convenience of the various AIEE technical committees and will include brief news reports of committee activities. Items for this department, which should be as short as possible, should be forwarded to R. S. Gardner at AIEE Headquarters, 33 West 39th Street, New York 18, N. Y.

Industry Division

General Industry Applications Committee (*V. O. Johnson, Chairman; F. D. Snyder, Vice-Chairman; E. M. Hays, Secretary*). The members of this committee believe that special conferences centrally located are more beneficial to industry than are technical conferences at national or District meetings. Consequently, four special conferences are definitely scheduled this year and others are in the formulation stage.

A Rubber and Plastics Conference has just been completed in Akron, Ohio, April 28, and a Textile Conference was held in Philadelphia, Pa., on April 24. Another Textile Conference for the Southern Group is scheduled this month in Atlanta, Ga. The Textile Subcommittee is preparing recommendations for lint-free enclosures for textile mills and is working very closely with National Electrical Manufacturers Association on this project. The other special conference is one planned for the Machine Tools Industry in Schenectady, N. Y., sometime this fall.

Power Division

General Systems Subcommittee (*R. L. Witzke, Chairman*). This subcommittee of the AIEE Transmission and Distribution Committee has participated actively in three projects: the line outage survey, the determination of distribution circuit recovery voltages, and the sleet melting session at the Winter General Meeting. The present status of each of these activities is as follows.

The line outage survey, which was made jointly with Edison Electric Institute, has been completed, and the results summarized in a "Report of Joint AIEE-EEI Subject Committee on Line Outages." The report was presented as a conference paper at the AIEE Summer General Meeting in Toronto, Ontario, Canada, last June and also was presented as a technical paper at the 1952 Winter General Meeting in New York. The presentation of this report will complete the assignment given to the Joint AIEE-EEI Subject Committee on Line Outages. This has been a major project, and the committee members should be commended for their efforts in carrying this assignment to a successful conclusion.

The AIEE Joint Subcommittee on Distribution Circuit Recovery Voltages, which is sponsored by the General Systems Subcommittee and the Lightning Protective Devices Subcommittee, has prepared a preliminary report which was presented as a conference paper at the 1952 Winter General Meeting. It is hoped that a final report can be completed in time for presentation as a technical paper at the Summer General Meeting in Minneapolis, Minn.

The General Systems Subcommittee has co-operated with the Towers, Poles, and Conductors Subcommittee in promoting papers for a conference session on sleet melting. A great deal of interest has been shown in this subject, and six papers were presented at the Winter General Meeting session on Thursday morning, January 24. However, there is still the problem of getting at least a part of this information on sleet melting into the *Transactions*, where it will be available for reference. The papers could be resubmitted as technical papers, if the Institute requirements can be met, or the contents of the papers could be summarized in a committee report. This problem will be reviewed for further study and the committee will decide then on what action should be taken.

The general opinion of the committee is that it would be desirable if papers from all parts of the United States having to do with the sleet melting problem could be included in a report.

It was suggested also that some analysis of the line outage report might be desirable which would discriminate between old and new construction. This will be left to the judgment of the subcommittee for further action.

Committee on Relays (*A. J. McConnell, Chairman; W. E. Marter, Vice-Chairman; Frank von Roeschlaub, Secretary*). A reorganization of one of the project committees has been made this year, calling for an increase in scope as well as in personnel of the group. Under the title "Project Committee on Co-ordination of Relay Protection of Industrial Power Systems With Utility Systems," with T. R. Halman as chairman, and augmented by representatives from the Committee on Industrial Power Systems, this group will work more in the field of education and publicity than of research. Emphasis will be placed on calling the industrial users' attention to the need for proper relay co-ordination, and on devising ways of providing help for him to do so. Preparation of papers will be encouraged with this end in view.

Since committee members from the West Coast have difficulty in attending meetings, it has been decided to establish a Pacific Coast Subcommittee. This group will report to the chairman of the Relay Committee, and it is expected that the interest of these remote members will be stimulated by this provision for an outlet through national organization channels.

Power Division

Committee on Power Generation (*J. A. Brooks, Chairman; J. B. McClure, Vice-Chairman; H. R. Harris, Secretary*). The January issue (*EE, Jan '52, p 98*) included a notice of the discussion session being arranged by the Hydroelectric Systems Subcommittee for the coming Summer General Meeting. Any questions pertaining to power generation, preferably in the hydroelectric field, may be asked. Whether or not members are planning to attend the 1952 Summer General Meeting, any questions of general interest to electrical engineers in the power generation field should be submitted to the AIEE Committee on Power Generation, 33 West 39th Street, New York 18, N. Y., before May 12, 1952.

Science and Electronics Division

Committee on Magnetic Amplifiers (*E. L. Harder, Chairman; W. J. Dornhoefer, Vice-Chairman; E. V. Weir, Secretary*). This committee was organized as a subcommittee of the Electronics Committee in the fall of 1951. The early work done on definitions and standards published in the progress report of the Magnetic Amplifier Subcommittee as AIEE paper 51-71 (AIEE *Transactions*, volume 70, 1951, pages 445-9) has proved very effective in establishing a common ground for discussion of these devices. Much uncertainty about terms, presentations of data, and the misunderstandings in regard to basic concepts have disappeared.

A wealth of technical and conference papers have appeared and these are all listed, together with the entire art, in paper 51-388, "A Bibliography of Magnetic Amplifiers and the Saturable Reactor Art" by J. G. Miles (AIEE *Transactions*, volume 70, 1951, pages 2104-23). The subcommittee, later the committee, has sponsored several technical sessions each year, one to three at each of the Winter and Summer General Meetings and several sessions at other meetings. It sponsored a session on applications at the 1951 National Electronics Conference.

The committee now functions through eight subcommittees, the activities of which are briefly recounted here. Persons interested in participating in this subcommittee work should get in touch with the chairman.

The Committee on Definitions is endeavoring to define such difficult terms as gain, time constant, and drift. The broad field of these devices, the innumerable types of applications and design variations, coupled with the nonlinear characteristics of the device itself, make it very difficult to provide uniformly significant definitions for these terms which can tie in with reasonable tests and provide a fundamental basis for standardization. This is a valuable contribution to the art and good progress is being made.

Further standardization work hinges on adequate definitions of time constant, drift, figure of merit, and so forth. Taking "drift" as a specific example, the drift of importance in various applications may be over a long period of time or a short time, may be due to aging, or to temperature changes. Hence, the significance of these factors must be considered in adopting a definition.

The Test Code Subcommittee expects to present an interesting program at the Summer General Meeting in Minneapolis. In discussing acceptance tests on cores, it developed that, in addition to fundamental tests which establish the characteristics of a core received from the manufacturer, a number of the fabricators are using various types of core matching tests and other special magnetic amplifier instrumentation upon which it would be very interesting to exchange notes and, if possible, to provide demonstrations at the meeting. This plan is materializing for the Summer General Meeting.

Committee on Basic Sciences (*M. G. Malti, Chairman; R. M. Bozorth, Vice-Chairman; W. C. Johnson, Secretary*). It has been found that the scope of the Subcommittee on Electrical Properties of Solids and Liquids was too vague and too inclusive. This subcommittee was, therefore, divided into two subcommittees; one on Dielectrics and the other on Semiconductors and Transistors.

There has been a great deal of interest in the subject of units, definitions, and standards; accordingly, at its meeting in January, the committee established a new Subcommittee on Units, Definitions, and Standards.

The committee is still interested in the idea of creating a Subcommittee on Defense. The chairman, however, reports that all efforts to secure the co-operation of The Research and Development Boards have been fruitless.

Subcommittee on Electron Tubes (*Scott Helt, Chairman; R. E. Higgs, Secretary*). A regular meeting of the subcommittee was held at AIEE Headquarters, New York, N. Y., on March 14, 1952.

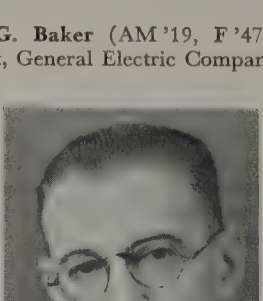
The eight working groups within the subcommittee structure have been completely reorganized and work is now under way towards the promulgation of standards on electron tubes of all types, this work being undertaken in such a manner that proposed standards will not conflict with those of other groups or professional societies. To insure against duplication of effort, liaison representatives have been appointed as follows: W. R. Clark, AIEE Instruments and Measurements Committee; H. Winograd, Electronic Power Converter Committee; D. E. Marshall, Joint Electron Tube Engineering Council Committee on Tubes; W. H. Whalley, American Physical Society; A. M. Glover, Institute of Radio Engineers Committee on Electron Tubes and Solid States Devices.

D. S. Peck, chairman of the Working Group on Gas-Filled Thermionic and Cold Cathode Tubes and Phototubes, is having his group prepare definitions of terms and test method on tubes in his specific field of activity, for standardization. Dr. L. B. Headrick, chairman of the Working Group on Cathode-Ray Tubes, is having members o his group prepare suggested standards of similar nature on cathode-ray tubes. D. E. Marshall has headed, for some time, a group in the preparation of standards on mercury-pool cathode tubes. J. R. Steen and his Working Group on Small Tubes for Entertainment Use is preparing standards on that subject.

The Standards Program on Electron Tubes is expected to be concluded before the end of the present year, at which time the standards developed will be submittted to the Electronics Committee and to the Standards Committee for final approval.

AIEE PERSONALITIES.....

W. R. G. Baker (AM '19, F '47), Vice-President, General Electric Company, Syracuse, N. Y., was awarded the Medal of Honor by the Institute of Radio Engineers. The medal, presented annually in recognition of distinguished service rendered through substantial and important advancement in the science and art of radio communication, was given to Dr. Baker for his "early technical contributions to the radio transmitter art, his long sustained and effective leadership of institute and industry engineering groups, and his outstanding service to the Institute." Dr. Baker was graduated from Union College with a degree in electrical engineering in 1916, a degree in mechanical engineering in 1918, and an honorary degree of doctor of science in 1935. He joined the General Electric Company's research laboratories in 1917, and the following year was made managing engineer of the Radio Department. In



W. R. G. Baker

1930, after the formation of the Radio Corporation of America, Dr. Baker was named head of the radio engineering activities of the new company and shortly afterwards became Vice-President and general manager. In 1935 he resumed his connection with General Electric and in 1939 he was appointed Vice-President. He is a very active member of the AIEE having served on the following committees: Award of Institute Prizes (1947–52); Electronics (1945–52, Chairman 1945–47); Standards (1945–47); Technical Program (1945–48); and Planning and Co-ordination (1947–50).

J. R. North (AM '21, F '41), Vice-President, Commonwealth Associates, Inc., Jackson, Mich., has been appointed to the Board of Directors of Commonwealth Services, Inc. Mr. North was graduated from California Institute of Technology with a bachelor of science degree in electrical engineering in 1923. For 1 year following his graduation he was employed by the Westinghouse Electric Corporation and then in 1924 he became associated with Commonwealth and Southern Corporation, attaining the position of chief electrical engineer in 1945. In 1949, when the Commonwealth and Southern Corporation was reorganized as Commonwealth Services, Inc., with an engineering subsidiary, Commonwealth Associates, Inc., Mr. North was appointed Vice-President of the latter organization. He is a member of the Society of Automotive Engineers and Tau Beta Pi. Mr. North has been a very active member of the AIEE serving as Director (1945–49) and is just completing a term of office as Vice-President representing the Great Lakes District (number 5). In addition he has served the Institute on the following committees: Protective Devices; Electric Machinery; Technical Program; Standards; Planning and Co-ordination; Air Transportation; Edison Medal; Switchgear; Publicity; and Technical Advisory.

J. R. North

Donald Glen Fink (M '45, F '51), Editor-in-chief, *Electronics*, McGraw-Hill Publishing Company, Inc., New York, N. Y., has joined the Philco Corporation, Philadelphia, Pa., as Co-Director of Research—Operations. Born on November 8, 1911, in Englewood, N. J., Mr. Fink was graduated from Massachusetts Institute of Technology (MIT) in 1933 with a degree of bachelor of science in electrical engineering, and from Columbia University in 1942 with a master of science degree in electrical engineering. After a year as research assistant on the staff of the departments of geology and electrical engineering at MIT, Mr. Fink joined the staff of *Electronics* as editorial assistant. In 1937 he became managing editor, in 1945, executive editor, and in 1946, editor-in-chief. Obtaining a leave of absence from McGraw-Hill in 1941, Mr. Fink became a member of the staff of the radiation laboratory at MIT where he headed the loran division. From 1943–45 he served as a consultant in the Office of the Secretary of War and in 1946 served as a civilian consultant at the atom bomb tests at Bikini. Mr. Fink is the author of several books in the electronic field and is a member of the Institute of Radio Engineers, Tau Beta Pi, Sigma Xi, and Eta Kappa Nu. He is currently serving the AIEE on the Electronics Committee and the Television and Aural Broadcasting Systems Committee.

H. B. Bryans (M '17, F '18), President, Philadelphia (Pa.) Electric Company, has retired after 45 years of service in the public utility business. He was born on March 26, 1886, in Philadelphia, Pa., and was graduated from the University of Pennsylvania in 1907 with a bachelor of science degree. Mr. Bryans was associated for many years with the Counties Gas and Electric Company, Norristown, Pa. In 1929 he was named Vice-President in charge of operations of the Philadelphia Electric Company, was elected Executive Vice-President in 1938, a Director in 1940, and President in 1947.

L. G. Cover (AM '20, M '40), manager, Cleveland Wire Works, General Electric Company, Euclid, Ohio, has retired after having completed 42 years of service with the company. Mr. Cover was graduated from Iowa State College in 1910 with a degree of bachelor of science in electrical engineering. He joined General Electric's Lamp Division the same year and since 1911 has been associated with the Cleveland Wire Works. He became assistant manager of the plant in 1920 and was named plant manager in 1950. He is a member of Tau Beta Pi.

E. A. Stanger (AM '45), distribution manager, and **Dan Anderson** (M '45), assistant plant manager, both of the Southern Canada Power Company, Ltd., Montreal, Quebec, Canada, have been promoted to the positions of assistant general manager and plant manager respectively. Mr. Stanger has been with the company since 1920. Associated with the company since 1943, Mr. Anderson is a member of the Engineering Institute of Canada.

K. A. Hoagland (AM '44), senior engineer, Tube Engineering Department, Allen B. Du Mont Laboratories, Inc., Clifton, N. J., has been appointed assistant engineering manager of the cathode-ray tube division of the company. Mr. Hoagland has been with the firm for 11 years and is considered an expert in the field of tubes. He is a member of the Institute of Radio Engineers, the American Physical Society, and Tau Beta Pi.

W. H. Happe, Jr. (AM '37), Director, vacuum tube division, Federal Telephone and Radio Corporation, Clifton, N. J., has been appointed works manager of the electronics division, Curtiss-Wright Corporation, Carlstadt, N. J. He is a member of the Institute of Radio Engineers, Tau Beta Pi, and Eta Kappa Nu.

V. R. Tate (AM '28, M '38), Executive Vice-President and Secretary, Perfex Corporation, Milwaukee, Wis., has been elected to the Board of Governors of the National Electrical Manufacturers' Association (NEMA). Mr. Tate has been active in the NEMA and for the past year has served as chairman of the automatic temperature controls section.

J. P. Growdon (AM '12, M '20), chief hydraulic engineer, Aluminum Company of America (ALCOA), Pittsburgh, Pa., has been made engineering consultant on hydraulic and related engineering problems for the company. Mr. Growdon joined ALCOA in 1925 as assistant hydraulic engineer.

E. T. Herbig, Jr. (AM '38), Director, alkaline cell division, Ray-O-Vac Company, Madison, Wis., has been appointed general sales manager of the E. F. Johnson Company, Waseca, Minn. In his new position he will direct all sales activities of the company.

J. M. Murray (AM '29, M '35), sales engineer, Simplex Wire and Cable Company, Cambridge, Mass., has been named assistant sales manager. Mr. Murray has been associated with the company since 1928.

E. R. Ausley (AM '51), electrical engineer, Allis-Chalmers Manufacturing Company, Milwaukee, Wis., has been assigned to the company's district office in Atlanta, Ga., as an electrical service engineer.

OBITUARY

Lewis Warrington Chubb (AM '09, F '21, Member for Life), retired, Westinghouse Electric Corporation, East Pittsburgh, Pa., died on April 2, 1952. He was born on October 22, 1882, in Fort Yates, N. Dak., and was graduated from Ohio State University in 1905 with the degree of mechanical engineer. Following graduation, Dr. Chubb joined the Westinghouse Electric Corporation as an engineering apprentice and from 1906 to 1910 he worked on the development and testing of sheet steel and did research on transformers. He was placed in charge of the electrotechnical and magnetic research work of the material and process engineering department in 1919. When the radio engineering department was organized in 1920, Dr. Chubb was made manager. He was made Director of Research in 1930 and held that position until his retirement from the company in 1948. He was granted more than 150 patents for electrical, mechanical, chemical, electrochemical, and instrumental developments. He received honorary doctor of science degrees from Allegheny College and from the University of Pittsburgh. In 1934 he was awarded

L. W. Chubb

the Lamme Medal of Ohio State University and in 1947 Dr. Chubb was awarded the John Fritz Medal. Author of many technical articles, he was a member of the American Association for the Advancement of Science, the American Physical Society, Franklin Institute, Institute of Radio Engineers, Illuminating Society, Tau Beta Pi, and Sigma Xi. A very active member of the AIEE, Dr. Chubb served on the following Institute committees: Electrophysics; Telephony and Telegraphy; Communications; Research; Award of Institute Prizes; Edison Medal; Code of Principles of Professional Conduct; Lamme Medal; Institute Policy; and Nucleonics.

Ralph Davenport Mershon (AM '95 M'96, F'12, Member for Life), retired, Greenwich, Conn., died on February 15, 1952. He was born in Zanesville, Ohio, July 14, 1868, and was graduated from Ohio State University in 1890. From 1891–1900 he was employed by the Westinghouse Electric and Manufacturing Company (now the Westinghouse Electric Corporation). In 1900 he entered private practice as a consulting electrical and mechanical engineer in New York City, and in this capacity designed and supervised many power plants and transmission systems in this country, Canada, South Africa, and Japan. Mr. Mershon was the inventor of the 6-phase rotary converter, the compounded rotary converter, systems of lightning protection for electric apparatus, and a compensating voltmeter, and he was the author of several technical articles. In 1918 he was awarded the honorary degree of doctor of science by Tufts College. Mr. Mershon was a very active member of the AIEE serving as Vice-President (1903–5), President (1912–13), and on the following Institute committees: Edison Medal (1911–16, 1925–30); Transmission and Distribution (1914–16); John Fritz Medal Board of Award (1913–16); Code of Principles of Professional Conduct (1924–28); Lamme Medal (1930–33); and Standards (1910–11).

John Millis (AM '84, M '85, Member for Life), retired, Colonel, United States Army, Cleveland, Ohio, died on March 20, 1952. He was born on December 31, 1858, in Wheatland, Mich., and was graduated from the United States Military Academy at West Point in 1881. As a first lieutenant attached to the third Lighthouse District of the United States Engineers he designed and executed the lighting system for the Statue of Liberty. In the early 1890's Colonel Millis was placed in charge of improving levees and the harbor of New Orleans, La. After serving 4 years as chief engineer of the United States Lighthouse Board, he inspected and reported on the canal and reservoir system of the Nile River in 1900, and then directed river and harbor improvements in Idaho, Montana, Washington, many other states, and Alaska. He wrote several books and articles on river flood control, practices to increase safety in navigation, and other engineering subjects. He was a member of the American Association for the Advancement of Science.

Paul Francis Shuey (AM '43), electrical engineer, North Electric Manufacturing Company, Galion, Ohio, died on January 3, 1952. He was born on July 14, 1881, in New Providence, Pa., and was graduated with a bachelor of science degree in electrical engineering from the University of Kansas in 1907. After holding various positions with several different companies, Mr. Shuey became associated with the North Electric Manufacturing Company in 1941. He was a member of the Institute of Radio Engineers and the Ohio Society of Professional Engineers.

John Broadus Taylor (AM '44), outside plant engineer, Pacific Telephone and Telegraph Company, Los Angeles, Calif., died on January 17, 1952. He was born on October 25, 1899, in Henderson, Ky. He attended the University of California, Berkeley, and the University of Southern California. He began his career with the Pacific Telephone and Telegraph Company in 1922 and advanced to the positions of division plant engineer in 1945, and outside plant engineer in 1950.

Albert S. Butler (AM '13, Member for Life), retired, Chicago, Ill., died on January 30, 1952. He was born in Bethany, Pa., on May 11, 1883, and was graduated from the University of Michigan with a bachelor of science degree in electrical engineering in 1907. He was associated with the Public Service Company of Northern Ill., Chicago, for 29 years, first as chief draftsman and later as supervisory design engineer. He retired from the company in 1949.

MEMBERSHIP • • • •

Recommended for Transfer

The Board of Examiners at its meeting of March 20, 1952, recommended the following members for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the Secretary of the Institute. A statement of valid reasons for such objections, signed by a member, must be furnished and will be treated as confidential.

To Grade of Member

Allsop, D. R., supervising service engr., Westinghouse Electric Corp., Salt Lake City, Utah
Barnes, T. D., mgr., watthour engg. sec., Westinghouse Electric Corp., Newark, N. J.
Burton, L. W., development engr., General Electric Co., West Lynn, Mass.
Cameron, D. H., elec. engr., Kansas City Power & Light Co., Kansas City, Mo.
Campbell, H. B., engr., U. S. Bureau of Reclamation, Billings, Mont.
Desai, M. D., chief engr. & mgr., The Surat Electricity Co., Ltd., Surat, India
Diehl, E. E., supt. meter dept., Toledo Edison Co., Toledo, Ohio
Dietze, T. W., dev. engr., General Electric Co., Schenectady, N. Y.
Dixon, A., mfg. engr., Westinghouse Electric Corp., East Pittsburgh, Pa.
Edmundson, C. W., chief engr., Stratford Engg. Corp., Kansas City, Mo.
Estoppey, R. F., senior electrical engr., Weston Electrical Instrument Corp., Newark, N. J.
Fielding, W. S., supervisor lab-engg. dept., General Electric Co., Pittsfield, Mass.
Garvie, W. L., engr., Industrial Electric Service Co., Crescent City, Calif.
Graves, W. K., electrical engr., Export-Import Bank of Washington, Washington, D. C.
Harp, C. E., asst. prof. of electrical engg., University of Oklahoma, Norman, Okla.
Harrison, G. E., 2641 Margate Ave., Victoria, B. C., Can.
Humphrey, A. J., dev. engr., Reliance Electric & Engineering Co., Cleveland, Ohio
Hunt, J. W., pres., Industrial Electric & Supply Co., Memphis, Tenn.
Karlskind, D. B., genl. mgr., Fesco, Inc., Little Rock, Ark.
Kees, E. G., design engr., Westinghouse Electric Corp. East Pittsburgh, Pa.
Kidd, K. H., research engr., Hydro Electric Power Commission of Ontario, Toronto, Ont., Can.
Langenwalter, D. F., elec. engr., General Electric Co., Schenectady, N. Y.
Leete, B. D., elec. engr., General Electric Co., Lynn, Mass.
Lyman, C. D., local mgr., Kansas City Power & Light Co., Ottawa, Kans.
Malloy, N. M., distribution engr., Luz Electrica de Venezuela, Caracas, Venezuela
Matney, T. L., electrical engr., Vitro Corporation of America, Richland, Wash.
McKeithan, W. L., section mgr., Westinghouse Electric Corp., Sharon, Pa.
Miller, W. H., electrical engr., The Hobart Brothers Co., Troy, Ohio
Ott, R. V., plant engr., Celanese Corporation of America, Narrows, Va.
Parker, J. E., utilities engg. supervisor, Carbide & Carbon Chemicals Co., Texas City, Tex.
Quist, A. H., Jr., electronic engr., Signal Corps Engineering Laboratories, Fort Monmouth, N. J.
Reynolds, R. H., Jr., project mgr., General Electric Co., Syracuse, N. Y.
Roberts, C. A., Jr., electrical engr., United Engineers & Constructors, Inc., Philadelphia, Pa.
Roughley, T. H., research engr., The Detroit Edison Co., Detroit, Mich.
St. Pierre, S. S., senior engr., Southwestern Bell Telephone Co., Oklahoma City, Okla.
Shirling, G. K,, equipment engr., Southwestern Bell Telephone Co., St. Louis, Mo.
Smart, T. E., electrical engr., National Carbon Co., Cleveland, Ohio
Swan, H. C., electrical engr., Sewerage & Water Board of New Orleans, La.
Swanson, M. C., development engr., American Locomotive Co., Schenectady, N. Y.
Theis, C. J., electric supt., Aluminum Co. of America, Cleveland, Ohio
Wanger, W., chief electrical engr., Brown, Boveri & Co., Ltd., Baden, Switzerland
Weddell, J. A., erection engr., Allis-Chalmers Mfg. Co., Pittsburgh, Pa.
White, E. A., electrical engr., U. S. Naval Air Development Center, Johnsville, Pa.
Whitton, A. W., asst. supt. of substations, Public Service Co. of Northern Illinois, Wheaton, Ill.
Wightman, F. R., engr., Public Service Co. of Northern Illinois, Chicago, Ill.
Williams, H. J., general supt., Carthage Water & Electric Plant, Carthage, Mo.
Williamson, R. B., partner, Williamson Sales Co., Shreveport, La.
Wouk, V., chief engr., Beta Electric Corp., New York, N. Y.
Wright, S. C., senior engr., Southwestern Bell Telephone Co., Oklahoma City, Okla.

49 to grade of Member

Applications for Election

Applications for admission or re-election to Institute membership, in the grades of Fellow and Member, have been received from the following candidates, and any member objecting to election should supply a signed statement to the Secretary before May 25, 1952, or July 25, 1952, if the applicant resides outside of the United States, Canada, or Mexico.

To Grade of Member

Crawford, W. G., Harland Engg. Co. Ltd., B. E. P. Works, Alloa, Scotland
D'Cruz, C., Elec. Dept., N.W.F.P. Govt., Peshawar, Pakistan
Hoag, S. B. (re-election), Chemical Construction Corp., New York, N. Y.
Illingworth, B. G., English Elec. Co. Ltd., c/o Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Subramaniam, N., International General Elec. Co., Ltd., Bombay, India
Thomas, M. A., H. Walton Redmile & Associates, Washington, D. C.

6 to grade of Member

Brookhaven Reactor at Upton, N. Y., Accessible for Peace-Time Research

Photographs showing certain structural details of the Brookhaven reactor have been released by the United States Atomic Energy Commission (AEC) for publication, it has been announced at Brookhaven National Laboratory. The Laboratory is operated by Associated Universities, Inc., under contract with the AEC.

The announcement follows removal from secrecy classification certain data of the reactors at Brookhaven and Oak Ridge (Tenn.) National Laboratory. Both are low-power reactors designed for research and production of radioisotopes, rather than for practical production of materials for atomic weapons. The Brookhaven reactor is the nation's largest research reactor and the only reactor in northeastern United States.

Declassification is intended to advance the art of reactor technology by assisting industrial concerns and universities now studying the feasibility of constructing their own reactors, for research or for production of energy which can be converted into electric power.

One side of the Brookhaven reactor, the west face, is available to all qualified scientists upon approval by the director of Brookhaven and by the AEC. The rest of the reactor is accessible only to persons with AEC security clearance.

The reactor proper is a 25-foot cube composed of some 60,000 pieces of graphite. Actually, however, the cube is split vertically in the center to provide a gap into which the thousands of cubic feet of air used to cool the reactor are introduced. After the air circulates through each half of the cube, it is collected in two spaces called plenum chambers before being discharged.

The cube and chambers are enclosed in a concrete shield 5 feet thick. Thus the over-all width is 38 feet, including shield, graphite, and center space between. The length is 55 feet, including shield, two plenum chambers, graphite, and central air gap.

A reactor of the Brookhaven type can be thought of as an atomic furnace in which graphite is the housing and uranium metal the fuel which burns or fissions, in a chain reaction. Tons of pure uranium metal are loaded through the holes of the south face of the reactor before uranium atoms can fission in a chain reaction. The reaction releases neutrons for use in experiments and for production of radioisotopes.

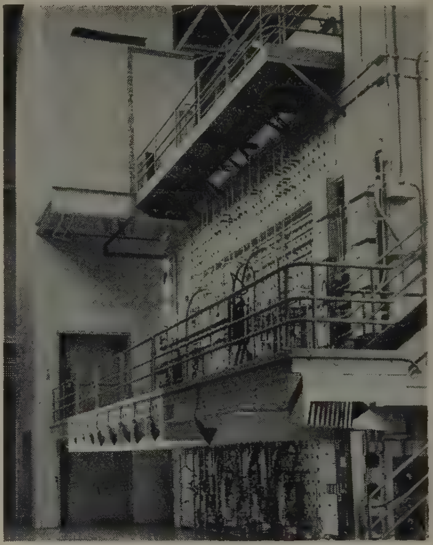
This side of the furnace is the loading face. It contains holes in rows and columns 8 inches apart. Most of the holes accommodate long aluminum cartridges, each containing uranium. Many of the holes are used to insert certain types of metals and other substances to be irradiated by neutrons. Some of these materials emerge with radioactivities of thousands of curies of beta and gamma rays, forms of radiation now used in industry and agriculture.

A pneumatic tube system occupies part of the north face of the Brookhaven reactor. The system can be compared to a change-making device in a department store. Here a sample of a material in a container can be inserted into one of the tubes and sped into the reactor, for bombardment by neutrons. It is returned quickly, radioactive for use in experiments.

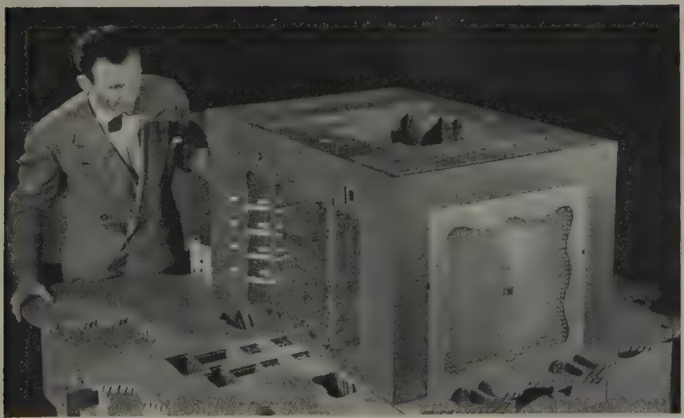
The system is useful in making radioisotopes of short half-life which lose half their radioactivity in seconds or minutes. Deliveries can be made either to this face of the reactor or directly into one of the several adjoining laboratories for use in connection with special experimental equipment.

Samples also are inserted at the east face for conversion into radioisotopes. Neutron beams are let out through special openings for studies of the properties of neutrons themselves or of materials they strike. In the picture of the east face the apparatus mounted on the reactor face at the far left is a conveyor, for moving samples of materials inside the reactor for exposure to neutrons. The materials are so altered by such exposure that they become radioactive and these radioisotopes have many uses in science, industry, and agriculture.

The cover of this magazine shows the west face of the reactor. On the first balcony,



A pneumatic tube system occupies most of the north face of the Brookhaven reactor. A sample of material in a container can be inserted into one of the tubes above or below the long balcony, sped into the reactor for bombardment by neutrons, and returned radioactive



On the left is a wooden model of the Brookhaven research reactor. The right-hand face of the cube represents the north face of the reactor. The left-hand face represents the east face of the reactor where neutrons can be let out of the large round ports. The picture on the right shows the east face in detail. In the center experiment neutrons are beamed from the reactor face, reflected by a mirror, then detected by a bank of counters inside the shielded array (center). Neutron counts are recorded on the panel at right which also supplies voltage for the counters

physicists and chemists are performing typical experiments with spectrometers for measuring the energies of neutrons in beams emerging from the reactor. The round ports can be used either to let out such beams or for inserting substances to be made radioactive inside the reactor.

On the ground floor and on the second balcony are health physicists with equipment for monitoring the ports to make sure that background radiation is kept below tolerance levels.

In the right foreground is one of the steel and concrete plugs used to seal off openings on the top of the reactor. The top, all four faces, and the bottom of the reactor (which is reached by tunnels) can be made use of in experiments.

Future Meetings of Other Societies

American Electroplaters' Society. 39th Annual Convention. June 16–20, 1952, Conrad Hilton Hotel, Chicago, Ill.

American Society for Quality Control. Sixth Annual Convention. May 22–24, 1952, Syracuse, N. Y.

American Society for Testing Materials. Annual Meeting. June 23–27, 1952, Hotel Statler, New York, N. Y.

Basic Instrumentation Conference. Fifth Conference. April 29–30, 1952, National Bureau of Standards, Washington, D. C.

Conference on Industrial Research. Third Annual Conference. June 9–13, 1952, Columbia University, New York, N. Y.

Edison Electric Institute. 20th Annual Convention. June 2–5, 1952, Cleveland, Ohio

Hydraulic Institute. June 1–3, 1952, The Cloisters, Sea Island, Ga.

Institute of Radio Engineers. Fourth Southwestern Conference and Radio Engineering Show. May 16–17, 1952, Rice Hotel, Houston, Tex.

International Lighting Exposition and Conference. Fourth Annual Meeting. May 6–9, 1952, Cleveland Auditorium, Cleveland, Ohio

International Organization for Standardization. Triennial Meeting. June 9–21, 1952, Columbia University, New York, N. Y.

National Air Pollution Symposium. May 5–6, 1952, Huntington Hotel, Pasadena, Calif.

National Association of Electrical Distributors. 44th Annual Convention. June 9–13, 1952, Atlantic City, N. J.

National Fire Protection Association. Annual Meeting. June 9–13, 1952, Hotel Statler, New York, N. Y.

Pennsylvania Electric Association. Systems Operation Committee Spring Meeting. May 22–23, 1952, Allenberry Lodge, Boiling Springs, Pa.

The American Society of Mechanical Engineers. Semiannual Meeting. June 15–19, 1952, Sheraton-Gibson Hotel, Cincinnati, Ohio

The Electrochemical Society Inc. 50th Anniversary Meeting. May 4–8, 1952, Benjamin Franklin Hotel, Philadelphia, Pa.

United States Navy's First Robot Pilot for Aircraft Carriers Developed

The United States Navy has accepted its first automatic steering system for aircraft carriers, it was announced recently by the Sperry Gyroscope Company, Great Neck, N. Y. The new robot helmsman will be installed aboard the *U.S.S. Oriskany*.

A magnetic brain, which anticipates steering motions, replaces conventional electron tubes used to control earlier automatic pilots. The magnetic brain was developed especially for heavy-duty naval use.

Without human aid, the robot will steer prescribed zigzags and follow course schedules computed by special navigation devices. It also will hold the ship precisely to straight gyro courses, despite disturbing forces of wind and sea. It is capable of turning the ship to a new course in the least possible time without overshooting the course.

New portable pilot will be used to steer ship from remote deck points such as the open bridge

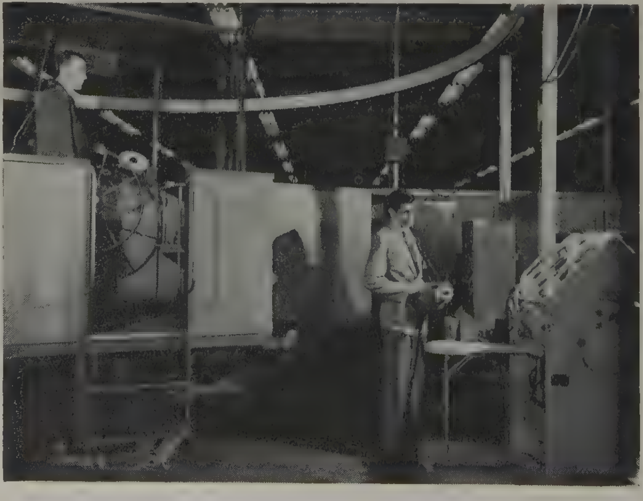
Deck personnel can take over and steer the ship manually at any instant simply by turning the manual steering wheel. They also can control the steering system from remote stations by means of a portable controller carried on a shoulder strap.

One use of the robot will be to steer the aircraft carrier into the wind during the launching and landing of aircraft. This operation requires keeping the wind a precise number of degrees off the port bow to neutralize the turbulent stream of air which flows around the ship's island. This course setting must be held within close tolerances.

The robot can aid the carrier in its role as a tanker for refueling ships while under way at sea. Accurate steering of the carrier on a straight course is essential because the receiving ship must sail within a reasonably close distance alongside without being pulled against the carrier. More accurate steering on the carrier makes it easier for the receiving ship to keep station on the carrier.

Advantage of automatic steering is that it can hold the ship's heading accurately over long periods of time. The robot also can follow a prolonged rapid flow of course change commands, such as might be occasioned in automatic tracking of targets or automatic evasive maneuverings.

The new robot's magnetic brain anticipates the ship's steering motions by measuring the ship's rate of turn. By comparing this rate to the ship's departure from the desired course, the brain is able to calculate how much opposing rudder it must apply to stop the ship's turn exactly on the desired course. The brain also contains an integrator which compensates for wind effects and errors in settling onto the new course.


Testing robot pilot's performance on a synthetic ship (left). The new automatic pilot's ability to steer large aircraft carriers under varying sea conditions was carefully checked in the laboratory at the Sperry Gyroscope Company, aboard a full-scale ship simulator. The simulator, can duplicate the behavior of any vessel from a submarine to a battleship. It consists of a turning bridge which is controlled by a battery of electronic calculators and recorders

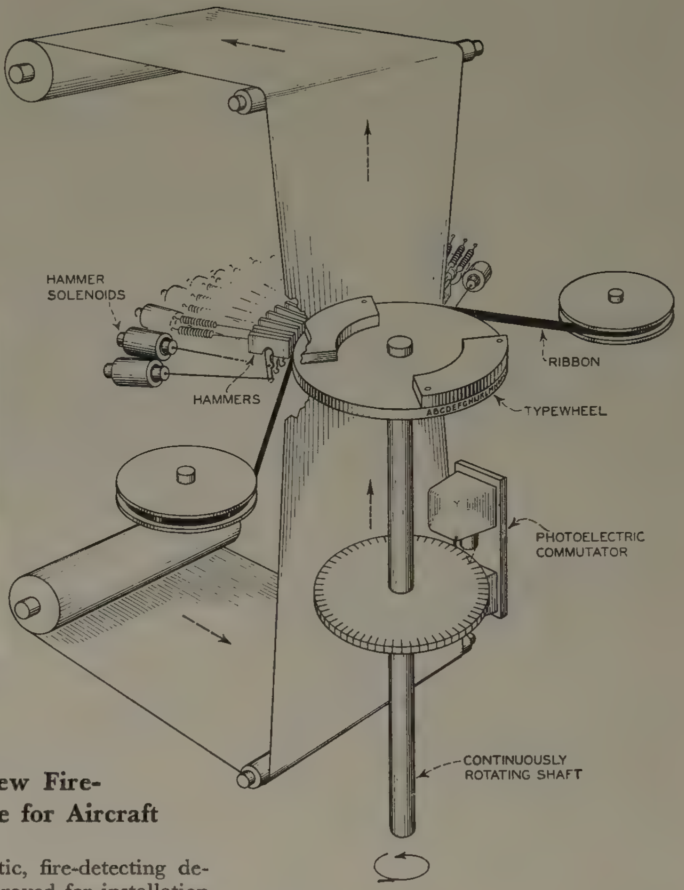
Flying Typewriter Prints 24,000 Characters a Minute

The new design of the "Flying Typewriter," announced by the Potter Instrument Company, Inc., Great Neck, N. Y., provides an answer to the need long felt in the fields of computing, data-handling, and communications.

This machine has a simple printing mechanism which is capable of reproducing 24,000 characters per minute. A total of 47 characters comprising the alphabet, numerals, and special other symbols are employed. A line at a time is printed using ordinary paper, standard typewriter ribbon, and hard-face type.

The major portion of the equipment is

(Left) High-speed writing equipment with electronic storage unit at left. The inset shows the relay-driven writing mechanism



(Right) Simplified diagram of the printing mechanism of the Flying Typewriter

an electronic serial-parallel storage unit. This accepts information in coded pulse form from an external source such as a computer, magnetic tape, punched cards, communication lines, and so forth. Eighty channels corresponding to the characters per line may be serial or parallel fed according to input requirements. Information is stored and extracted alternately in these channels, completing this cycle once for each line printed.

The type is arranged in segments about the periphery of an 8-inch disk rotating in a horizontal plane at 300 rpm. Eighty hammers arranged in an arc parallel to the type wheel are impulsed electromechanically at appropriate times against the type faces according to instructions from the electronic storage. The impression is registered on regular paper which is fed intermittently upward from a roll and conforms to the curve of the type wheel.

A photoelectric pulse generator on the shaft of the print wheel is used to precess the characters out of the electronic storage. The system is self-synchronous and can be operated on a continuous or intermittent basis.

The electronic storage, which is essentially an extremely flexible shift register, may be used as part of a computer to perform addition, subtraction, division, and multiplication. It also may be used to shift the information being printed to any selected columns.

Of particular advantage in communications is the Flying Typewriter's ability to be fed serially over a channel of telegraph bandwidth. The printing can be controlled by the input to be intermittent or continuous.

Wide application is suggested where mass filing of information on business machine cards and magnetic or punched tape calls for convenient and extremely rapid access and translation. Among other applications are printing magazine address strips, invoices, statistical reports, and premium notices.

CAA Approves New Fire-Detecting Device for Aircraft

A sensitive, automatic, fire-detecting device has just been approved for installation in commercial aircraft by the Civilian Aeronautics Administration (CAA). The equipment also has completed qualification tests by the United States Air Force and the Bureau of Aeronautics (Navy) for use on military aircraft, and is now in production by Walter Kidde and Company, Inc., Belleville, N. J.

The system comprises a continuous wirelike, fire-sensing element connected at one end to a monitoring control unit, which in turn provides the power for the system and the electronic circuit for actuating audible and/or visible alarms, which are located on the pilot's instrument panel. The other terminal of the sensing element is connected to a relay circuit for preflight and in-flight testing.

The sensing element consists of two small inconel conductor wires surrounded by insulating ceramic material, all of which is incased in a thin-wall inconel tube. The insulating ceramic is in tiny bead-like cylinders making the sensing element highly flexible, while the inconel covering gives the element strength.

At normal temperatures the ceramic offers high resistance to the flow of current between the two conductor wires. However, when subjected to increasing temperatures, as encountered with fire, the resistance of the ceramic drops rapidly and permits a flow of current between the two wires. This flow of current is interpreted by the monitoring control unit in terms of degrees of temperature and when a predetermined temperature is attained the alarms are actuated. When the temperature returns to normal, the resistance of the ceramic is restored and the alarms shut off indicating that the fire is out. No manual operation is necessary for resetting.

Light in weight, 0.0065 pound per foot, the sensing element is only 0.065 inch in diameter and is flexible. It is not damaged by vibration or flexing. The sensing element comes in lengths up to 20 feet and 100 feet of coupled elements can be used in conjunction with each control unit. The sensing elements can be installed in a single strand, completely encircling a power plant installation, thus insuring positive fire detection.

The sensitive element assures a fire alarm signal within 3 seconds after it has been subjected to flame. Following the extinguishment of a fire, the wire returns to its original no signal state in about 15 seconds.

Sensitive Electronic Duplicator Speeds Precision Machining

The single motion duplicator, a new device with a "finger" more sensitive than those of human hands, is speeding up the precision machining of metal parts for vitally needed equipment. Through the use of this electronic robot that feels the contours of a master pattern, hundreds of parts, which are the exact duplicates of the original, are machined more accurately and in less time than by manual operation. It was developed by Raytheon Manufacturing Company, Waltham, Mass., and distributed by the Voss Engineering Company, Pittsburgh, Pa.

In the field, the duplicator is used in turning shafts, bearings, pulley sheaves, mill rolls, printing machine rolls, commutator rings, and similar parts of irregular contour.

It has been used in die-sinking operations and in producing cams of complicated design on milling machines. In many of these applications, the average time for completing a single part has been reduced as much as 80 per cent and spoilage by at least 20 per cent. The duplicator also aids in saving critical materials which are in demand in the emergency effort.

The duplicator consists of a follower, an electronic control unit, and an output drive motor. The follower is a variable reluctance transducer whose electric output varies in accordance with the contours of a template. This signal is amplified and detected in the electronic control unit, providing drive to the output motor. The motor, in turn, positions the follower and cutting tool. Thus, the contour of the template is reproduced automatically on the work.

High-Speed Correction Lens Improves Schmidt Optical System

A new projection optical system with a speed of f0.67 has been developed by General Precision Laboratory, Inc., Pleasantville, N. Y. Using only the light from the face of a high-intensity 7-inch television picture tube, the Simplex projects a 25×19 foot picture on a theater screen 78 feet away. As a result of the speed and light transmitting ability, screen illumination is uniform over the entire picture area, without any center hot spot.

Like the classical Schmidt system, the main elements of the Simplex consists of a spherical reflecting mirror, a diaphragm or annular ring which acts as a fixed iris, and a correctorplate which is a thin lens ground to a special curvature to correct nearly all of the aberrations of the spherical reflector. This lens is 22.2 inches in diameter.

All three fit into a projection barrel; mirror at rear, lens in front, and diaphragm approximately in the center. The picture tube is mounted in the center of the barrel.

Focal length of the system, 384 millimeters or 15.3 inches, is determined by the radius of the 7-inch picture tube, the 7-inch size being the practical limit, since any larger sized tube would cut off too much light.

Typical of the calculations involved in formulating this new optical system was the ray-tracing project which was set up. For each point on the lens profile, a cross section of ray tracings from the spherical mirror had to be made. Off-axis aberrations in this system are only one quarter of those in the conventional Schmidt system. The ratio of geometrical apertures, efficiency of light transmission at the edge versus center, is 0.6 in the usual Schmidt type while in this system it is advanced to 0.9.

The alignment of the three main elements is extremely critical in this system. But it was found that additional efficiency could be gotten by moving the position of the diaphragm slightly to the rear, towards the spherical reflector. The diaphragm stops down the system to a working speed of f0.78.

Using the evolved formula, the corrector was cast and ground for the General Precision Laboratory by the American Optical Company, which developed production methods to make such a lens economically practical.

Made of lead glass, the lens is ground flat on both sides and brought to a certain thickness and diameter. It is placed over a porous mold shaped to desired lens profile, then heated to a point where it is barely plastic. Vacuum is applied through the mold from below and the lens is gradually pulled down to the required curvature.

When it cools, the back side is ground optically flat, leaving the face in profile form. As a final production process, the lens is coated by a spinning and spraying process.

The spherical mirror is 26 inches in diameter, is approximately 2 inches thick, and is coated with an extremely thin layer of aluminum. So thin is the coating that it is not entirely opaque. But the extra-thin coating, even with random pinhole losses of light, gives better reflection value than a heavier coating of 100 per cent opacity.

The projection barrel is sealed to eliminate electrically attracted dust. A recirculating cooling system holds down temperature of the tube, which is operated at a far higher voltage than in normal receivers.

Picture quality is controlled from a console panel which is set up in a remote position from the projector barrel. The operator can tell, from instruments and monitor cathode-ray tubes on the console, the exact signal quality that is coming into the line and can adjust the projected image for best viewing results. Reception of both video and audio signals may be either by coaxial cable, microwave, or off the air.

Canada and U. S. Accept Standard Marine Radiotelephone System

A treaty was signed on February 21, 1952, between Canada and the United States, providing for a uniform system of marine radiotelephony with the object of promotion of safety of life and property on the Great Lakes and as an aid to navigation. The document was signed by the Honourable Lionel Chevrier, Canadian Minister of Transport, by the Honourable Stanley Woodward, United States Ambassador to Canada, and by Commissioner E. M. Webster of the Federal Communications Commission, Washington, D. C.

Signing of the treaty between the two countries brings to completion the discussions held in Ottawa in May 1951, between governmental authorities and the shipping interests concerned, and the negotiations which have been conducted by Commissioner Webster and his Canadian counterpart dating back to prewar years. The treaty is effective on the Great Lakes and their navigable connecting and tributary waters as far east as Montreal.

The treaty provides for the authorized use of radiotelephony as a means of communication of distress signals for shipping on the Great Lakes with the distress frequency 2,182 kc and the present working frequencies being continued. It further agrees on the need for making compulsory the carriage of radiotelephone equipment on all lake shipping of 500 gross tons and over, and on all passenger-carrying vessels over 65 feet in length. All such vessels and all shore stations would be required to maintain constant listening watch on the distress-calling frequency.

North Pacific Radio Warning Service Made Available by NBS

The first systematic forecasts of radio propagation conditions in the North Pacific and Alaskan areas were issued recently by the National Bureau of Standards (NBS) Radio Propagation Field Station in Anchorage, Alaska. This latest aid to all users of radio communications serves the same function for these areas as does the North Atlantic Radio Warning Service at Washington, D. C.

At present, the NBS service makes available to operators of communication systems an advance forecast applicable to radio transmissions in three service areas illustrated by the following typical paths: from Alaska to Seattle, Wash., and San Francisco, Calif.; from Alaska to the Aleutians and Tokyo; and within Alaska. The forecast, which is revised and reissued twice each week, lists the likely periods of disturbance in the 25 days after issue and includes specific estimate of propagation conditions for the first 7 days of the forecast period.

Other types of forecasts are being prepared. One is a twice-daily forecast of conditions on the Anchorage-Seattle radio circuit, which has had a 6-month test with limited distribution. NBS also is testing regional forecasts for each of the three North Pacific areas.

Disturbances to radio propagation have long hindered communications in the Alaskan area. Interruptions of several days are not uncommon on some high-frequency radio circuits and these interfere seriously with the normal conduct of affairs wholly dependent on rapid communications. Advance warning of disturbances, which result from the magnetic fields of the nearby auroral zone, together with forecasts of the day-to-day quality of propagation conditions, will lead to more efficient use of the short-wave radio spectrum for communications in that area.

The North Pacific Radio Warning Service is designed to supply this vital need. Special observations are carried on at Anchorage, and magnetic, ionospheric, and circuit-performance observations throughout the Alaskan and northwest Canadian area are reported promptly every day or oftener to the forecasting center. In addition, the Warning Service at Anchorage has available up-to-date solar activity information and other data sent regularly from NBS in Washington.

Practical radio circuit quality includes many types of effects, but it is found that the indexes of quality compare more closely with magnetic disturbance variations than with any other single ionospheric characteristic. Therefore, the magnetic condition is given most weight in radio disturbance forecasting. The magnetically disturbed periods often can be forecast several days or weeks in advance from solar-terrestrial relationships or from the marked tendency for magnetic disturbances to recur at about 27-day intervals. Occasionally a forecast can be made a few hours in advance of the beginning of a severe disturbance, if a very intense solar flare is observed, for instance.

Because both magnetically disturbed and quiet periods tend to last several days, the general level of magnetic disturbance usually can be estimated for a few hours or a day ahead. These short-term magnetic forecasts are interpreted in the light of current ionospheric and radio propagation observations and result in a prediction of the anomalies that can be expected to develop in the ensuing 12 or 24 hours. The degree of success of these estimates varies widely, just as do the strength of the various correlations used. About 85 per cent of the predictions of disturbances are correct; and 90 per cent of the disturbed days are predicted in short-term forecasts, an appreciably better record than that attained by the advance forecasts.

Indiana Engineering Council to Sponsor Engineering Exposition

Alumni, engineers, and college and high-school students will convene at Purdue University, Lafayette, Ind., May 2–4, 1952, to attend the Indiana Engineering Exposition. This exposition is being sponsored by the Indiana Engineering Council for the purpose of showing students and the public the opportunities in the engineering profession. The exposition will tie together the role of engineering education and the part engineers play in industry in general.

C. F. Kettering, Vice-President, Director, and General Manager of the Research Laboratories of the General Motors Corporation, will deliver an address.

The Indiana Engineering Council is a statewide organization with which the local sections in Indiana of the major national professional engineering societies are affiliated.

The Engineering Manpower Commission of the Engineers Joint Council, which has a vital interest in encouraging more qualified high-school graduates to enter the engineering profession, will participate in the exposition.

CIGRE Conference to Be Held in Paris, France, May 28–June 7

At a recent meeting of the United States National Committee of CIGRE (International Conference on Large Electric High-Tension Systems) plans were formulated for United States participation in the 14th Biennial Session of CIGRE, which is to be held in Paris, France, from May 28 to June 7, 1952.

These conferences are attended by 1,500 delegates from 40 different countries and are devoted to a discussion of all problems relating to the generation, transmission, and distribution of electric power. They are of particular interest to executives and design and operating engineers in both the electric power and also the electrical manufacturing industries.

One hundred and twenty technical papers are to be presented at the June conference, of which 13 will be of United States authorship.

There are 1,650 permanent members of CIGRE in 45 countries and 230 individual permanent members and 18 collective permanent members in the United States.

Arrangements have been made for a large and representative United States delegation to attend the 1952 conference. Further information and registration forms may be obtained from Frederic Attwood, Chairman, United States National Committee of CIGRE, Room 1761, 50 Church Street, New York 7, N. Y.

LETTERS TO THE EDITOR

INSTITUTE members and subscribers are invited to contribute to these columns expressions of opinion dealing with published articles, technical papers, or other subjects of general professional interest. While endeavoring to publish as many letters as possible, Electrical Engineering reserves the right to publish them in whole or in part or to reject them entirely. Statements in letters are expressly understood to be made by the writers. Publication here in no wise constitutes endorsement or recognition by the AIEE. All letters submitted for publication should be typewritten, double-spaced, not carbon copies. Any illustrations should be submitted in duplicate, one copy an inked drawing without lettering, the other lettered. Captions should be supplied for all illustrations.

Force on a Conductor in a Slot

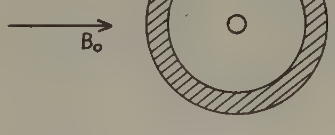
To the Editor:

Electrical engineers, in general, have analyzed electric machinery by use of the force law:

$F = iBL$

where B is taken as the air gap flux density. However, in machines the conductors are imbedded deeply in slots and in some cases are completely surrounded by iron, so that the actual flux density in the conductor is a small percentage of the air gap flux density. Therefore, how can correct answers be obtained using the air gap flux?

Figure 1. Cross section of long conductor in iron sleeve



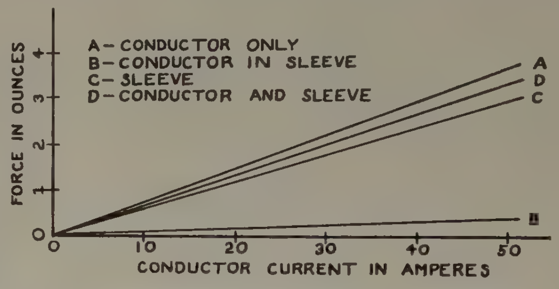


Figure 2. Magnetic forces measured on conductor and sleeve

A general answer to the question has been attempted in Cullwick's, "The Fundamentals of Electromagnetism," although the answer is not in satisfying form. Therefore, the writers have analyzed the following problem in detail: In Figure 1 is shown a cross section of a long conductor carrying a current i on the axis of a circular iron sleeve of relative permeability μ_r. The field B_0 perpendicular to the axis was a uniform field before the wire and iron sleeve were introduced. Use of the force equation shows that the force on the wire is small, since the magnetic shunting action of the sleeve causes the flux density in the wire to be a small fraction of B_0. An electrical engineer well versed in iBL finds no force on the sleeve, although he does not question the origin of that force which attracts soft iron toward regions of higher flux density.

The problem was analyzed mathematically by assuming no variation along the axis of the conductor. The actual fields in the iron and the conductor were found by solving a boundary value problem, and the forces on the wire and on the iron sleeve were found by integrating the stress tensor over appropriate enclosing surfaces. The result was, as might be expected, that the total force on both the conductor and the sleeve was iB_0L, although the actual division of the total force between the conductor and sleeve depended on the relative permeability of the sleeve. In particular, for high permeability iron the force on the conductor was found to be negligible. It may be said that the function of the current is to distort the otherwise uniform field which exists in the absence of the iron sleeve so that when the latter is inserted into the field it experiences a force.

The theoretical results seemed to the writers to be worthy of experimental verification. The magnetic field of an old magnetron magnet was utilized, and forces were measured by suspending the body by string from a balance scale. Current was fed to the wire by mercury cup connections. This allowed the use of large currents without destroying the accuracy of the experiment with stiff connecting cables.

The forces on the conductor without the presence of the sleeve, on only the wire inside the iron sleeve, and on only the iron sleeve with the conductor carrying current, were measured. The results are presented in Figure 2. The force on the conductor without the presence of the iron sleeve agreed well with the total force on both conductor and sleeve, considering that the experimental accuracy was not high.

C. R. CAHN

D. W. SPENCE (AM '50)

(Electrical Engineering Department, Syracuse University, Syracuse, N. Y.)

NEW BOOKS • • • • •

The following new books are among those recently received at the Engineering Societies Library. Unless otherwise specified, books listed have been presented by the publishers. The Institute assumes no responsibility for statements made in the following summaries, information for which is taken from the prefaces of the books in question.

CHAUFFAGE ET SECHAGE PAR LAMPES A RAYONNEMENT INFRA-ROUGE. By M. La Toison. Editions Eyrolles, 61, Boulevard Saint-Germain, Paris (5^e), France, 1951. 112 pages, tables, diagram, 9¾ by 6½ inches, paper, Ffrs. 790. Covers heating and drying by means of infrared radiation. General principles of heat transfer and the characteristics of infrared lamps are dealt with prior to the specialized treatment of infrared utilization. Several actual installations are briefly described in the final chapter.

THE CONDUCTION OF ELECTRICITY THROUGH GASES. (Methuen's Monographs on Physical Subjects). By K. G. Emeléus. John Wiley and Sons, 440 Fourth Avenue, New York 16, N. Y. Third edition, 1951. 99 pages, diagram, charts, tables, 6¾ by 4¼ inches, cloth, $1.50. This small book provides concise coverage of the main phenomena which can be studied quantitatively in connection with the passage of electricity through gases at low pressures, in particular those associated with the glow-discharge. The chapter headings demonstrate the scope of the work: initiation of the discharge; cathode phenomena; exploring electrodes; negative glow, Faraday dark space, and anode glow; positive column of glow-discharges; miscellaneous phenomena.

ELEMENTS D'OPTIQUE ELECTRONIQUE. By Gaston Dupouy. Librairie Armand Colin, 103, Boulevard Saint-Michel, Paris, France, 1952. 218 pages, diagrams, charts, 6½ by 4½ inches, paper, Ffrs. 260. Following an introductory chapter, the author discusses the refraction and reflection of electrons in an electric field. Subsequent chapters cover in detail the construction, characteristics, and performance of both electrostatic and magnetic electronic lenses. Aberration and other problems are discussed, and the analogies and differences between glass lenses and electronic lenses are indicated. The final chapter takes up the electronic microscope and its use.

ENERGY SOURCES—THE WEALTH OF THE WORLD. By Eugene Ayres and Charles A. Scarlott. McGraw-Hill Book Company, 330 West 42d Street, New York 18, N. Y., first edition, 1952. 344 pages, illustrations, charts, tables, 9¼ by 6½ inches, cloth, $5. This analysis of a highly important problem provides a detailed review of the size of energy sources, technology of production, efficiency of conversion, and the progress being made in conversion. Oil, coal, gas, hydroelectric power, solar and nuclear energy, wind, tidal power, and other minor sources, all are assessed and dealt with according to their relative importance. An "energy balance sheet" for the United States is tabulated and discussed in the last chapter.

ENGINEERS' ILLUSTRATED THESAURUS. By Herbert Herkimer. Chemical Publishing Company, Inc., 212 Fifth Avenue, New York, N. Y., 1952. 572 pages, diagrams, 8¼ by 5¾ inches, cloth, $6. More than 8,000 machine elements from simple handles and clamps to complex mechanisms and special devices are named and illustrated, with brief explanations where necessary. They are grouped in the following broad classifications: fasteners, adjusting devices, supports and structures, basic mechanical movements, hoisting and conveying equipment, transmission of liquids and gases, combustion, prime movers, transportation, industrial processes, electric appliances, heating, and air conditioning.

FRACTIONAL-HORSEPOWER ELECTRIC MOTORS. THEIR PRINCIPLES, CHARACTERISTICS, AND DESIGN. By F. G. Spreadbury. Sir Isaac Pitman and Sons, Ltd., London, W.C.2, England, 1951. 342 pages, illustrations, diagrams, charts, tables, 8¾ by 5¾ inches, cloth, 35s. A detailed treatment is given of the important types of these small motors, beginning with two chapters on d-c units. The following chapters take up polyphase and single-phase induction motors, the universal motor, the repulsion motor, and synchronous motors. Hysteresis, permanent magnet, and other miscellaneous types of motors are briefly considered. Separate chapters are devoted to motor control and to the performance characteristics of fractional-horsepower motors.

FUNDAMENTALS OF ATOMIC PHYSICS. By Saul Dushman. McGraw-Hill Book Company, Inc., 330 West 42d Street, New York 18, N. Y., first edition, 1951. 294 pages, diagrams, tables, charts, 9¼ by 6¼ inches, cloth, $5.50. Designed to be as simple as possible in treatment, this book gives engineers and other technical men a practical knowledge of atomic and nuclear fundamentals. Topics covered include the kinetic theory of gases, the charge and mass of the electron, electronics, photoelectric effects, X rays, matter waves, isotropes, and a condensed presentation of nuclear phenomena. The final chapter gives the characteristics of the several types of generators for the acceleration of high-energy particles, the cyclotron and betatron.

GENERAL NETWORK ANALYSIS. By Wilbur R. LePage and Samuel Seely. McGraw-Hill Book Company, 330 West 42d Street, New York 36, N. Y., first edition, 1952. 516 pages, diagrams, tables, 9¼ by 6¼, cloth, $8. A comprehensive textbook covering the following broad classes of network analysis: steady state in lumped networks, steady state in distributed systems, transients in lumped networks. A number of specialized techniques of fundamental importance are included such as matrices, symmetrical components, transmission-line charts, Fourier series, Fourier integral, and the Laplace integral. The book is intended to provide a background for advanced work in either power or communications.

A HISTORY OF THE THEORIES OF AETHER AND ELECTRICITY. Volume 1. The Classical Theories. By Sir Edmund Whittaker. Philosophical Library, 15 East 40th Street, New York 16, N. Y., 1951. 434 pages, 9¾ by 6½ inches, cloth, $12. This considerably revised edition of a work originally published in 1910 constitutes the first volume of a 2-volume set and covers the period from Aristotle to the end of the 19th century. All the important contributions are dealt with in logical groupings providing a steady chronological development and an effective indication of the part played by each of the various contributors, a roll call of the great names of science. The book is well documented. A second volume will continue the story in a similar manner to the present time.

MATERIALS TECHNOLOGY FOR ELECTRON TUBES. By Walter H. Kohl. Reinhold Publishing Corporation, 330 West 42d Street, New York 18, N. Y., 1951. 493 pages, illustrations, diagrams, tables, charts, 9¼ by 6¼ inches, cloth, $10. The materials dealt with are the main solids which enter into the construction of electron tubes: glass, ceramics and mica, tungsten, molybdenum, tantalum, nickel, copper, carbon, and graphite. Physical and chemical characteristics are tabulated and discussed, processes for application are considered, and modern techniques of construction are described. Special topics are taken up in later chapters: ceramic-to-metal seals, the phase rule, high-vacuum technique, and thermionic emission.

THE THEORY OF ELECTROMAGNETIC WAVES. A Symposium, June 6–8, 1950. Under the auspices of the Washington Square College of Arts and Sciences, The Institute for Mathematics and Mechanics of New York University, and the Geophysical Research Directorate of the Air Force Cambridge Research Laboratories. Interscience Publishers, Inc., 250 Fifth Avenue, New York 1, N. Y., 1951. 393 pages, charts, diagrams, 10¼ by 7 inches, cloth, $6.50. Reflecting the definite revival of interest in electromagnetic problems, the 18 papers contained in this volume present current approaches by the use of new analytical tools and procedures. Essentially mathematical in character, these papers utilize Green's functions, integral equations, variational techniques, and so on, in dealing with problems concerning wave propagation, wave guides, cavity theory, microwave generation, and similar subjects. This material also appeared in three recent issues of the publication, "Communications on Pure and Applied Mathematics."

TRANSIENTS IN ELECTRIC CIRCUITS—USING THE HEAVISIDE OPERATIONAL CALCULUS. By W. B. Coulthard. Sir Isaac Pitman and Sons, Ltd., Pitman House, Parker Street, Kingsway, London W.C.2, England, second edition, 1951. 260 pages, diagrams, 8¾ by 5¾ inches, cloth, 32s.6d. This study of electric transients in a-c circuits has been enlarged to include discussions of the Fourier series and Fourier integrals, operation of synchronous machines, electromechanical devices, spot welders, linear control systems, and operational methods of analyzing periodic wave forms. The book is of particular interest to electrical engineers engaged in power transmission, telecommunications, and in the design of switchgear and electric machines where the effect of current surges have to be predicted and provided for.

PAMPHLETS • • • • •

The following recently issued pamphlets may be of interest to readers of "Electrical Engineering." All inquiries should be addressed to the issuers.

NEMA Standards for Electric Power Connectors. This revision of Publication Number *37-47* contains standards for the current ratings of bare copper and aluminum conductors; rated frequency; basis of temperature rise; identification marking; thread dimensions; and bolts, nuts, and lockwashers for connectors. Information is given also concerning the temperature rise, resistance, strength, and radio influence voltage tests. The various types of connectors are defined and classified. $2.00 per copy. Publication Number *SG1-1952*. Available from the National Electrical Manufacturers Association, 155 East 44th Street, New York 17, N. Y.

Hydraulic Research in the United States, 1951. To provide a guide to the current and completed projects conducted by various hydraulic and hydrologic laboratories in the United States and Canada. Project reports in the volume cover work done at 66 private or state laboratories in the United States, 34 Federal Laboratories, and 5 Canadian laboratories. Outline given of individual projects being conducted on nearly 200 subjects in the field. 190 pages, $1.25 per copy. Obtainable from the Government Printing Office, Washington 25, D. C.

Plastic Deformation of Crystalline Solids. Sponsored jointly by the Carnegie Institute of Technology and Office of Naval Research, report consists of 19 papers by authorities in special areas of plastic deformation of crystalline materials. Knowing the regular atomic arrangements within crystals, and what it takes to dislodge individual atoms from these regular arrangements will enable engineers to develop better, stronger, crystalline materials, especially metals. 226 pages, including photographs, diagrams, and graphs. $3.50 per copy. Available from the Office of Technical Services, United States Department of Commerce, Washington 25, D. C.

On the Mechanics of Magnetic Amplifier Operation. Reported results of an investigation made by the Naval Research Laboratory and a descrpition of a magnetic amplifier circuit which was developed. Superior to magnetic amplifiers now in use, it has an amplification approaching 10,000 and less than 1-cycle response time. 29 pages including graphs. 75¢ per copy. Available from the Office of Technical Services, United States Department of Commerce, Washington 25, D. C.

Complete Guide to Successful Silver Brazing. Complete report on all aspects of silver brazing applications and procedures. Information given on low-temperature brazing, brazing alloys, joint design, preformed brazing shapes, plymetals, fluxing, heating methods, cleaning, and inspection. Reference charts and graphs. Available upon request from American Platinum Works, 231 New Jersey Railroad Avenue, Newark, N. J.

The power transformer winding that meets all the requirements for very high voltage

"Concentric Layer" windings provide important advantages on all G-E transformers 750-kv BIL and above

- **Uniform distribution of impulse voltages** and the elimination of harmful oscillations are characteristic of "concentric layer" construction. As a result, voltage stresses can be calculated accurately and insulation applied precisely as required.

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G-E "concentric layer" transformers now being built at a rate of 2,500,000 kva per year!

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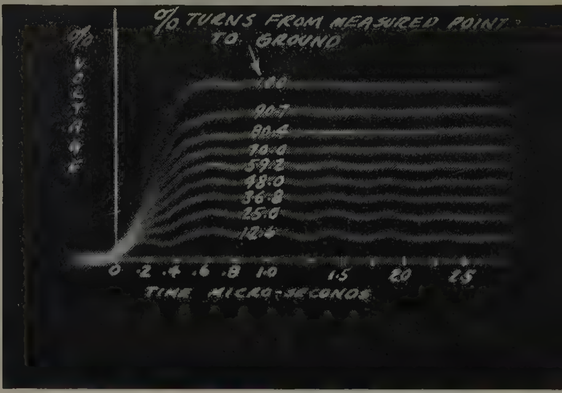
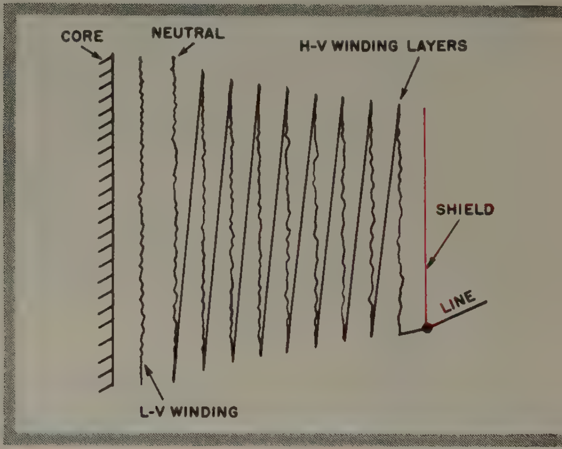
If you are contemplating voltages of 161-kv and above, you may wish to review the data on these windings. Ask for GER-129. Address inquiries to your nearest G-E Apparatus Sales Office, or write directly to Section 401-28, General Electric Company, Schenectady 5, N. Y.

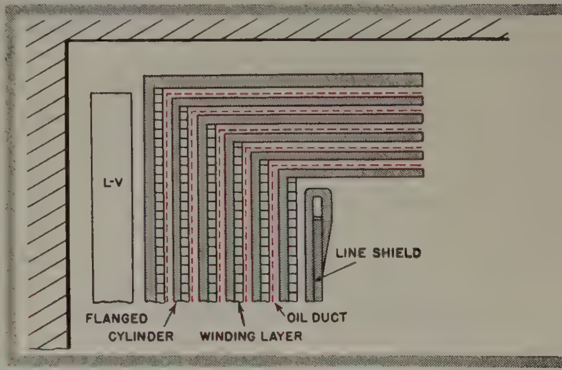
> **"Concentric layer" windings** consist of a number of cylindrical layers arranged concentrically, as shown on these pages. The innermost layer, adjacent to the low-voltage winding, is connected to the neutral. Then, successive layers are connected in series progressively, with the outer layer being connected to the line.
>
> Basic insulation is provided by cylinders of insulating material. These cylinders are flanged over the ends of the winding to eliminate creepage paths in the direction of high electrical stress. The *entire* winding is protected from transient voltage stresses by electrostatic shielding.



ACTUAL OSCILLOGRAM showing voltage to ground at equally spaced points in the winding when 0.6 x 190 microsecond impulse wave was applied to line end. Absence of large oscillation is indicative of uniform impulse distribution.



WINDING CONNECTION DIAGRAM shows that voltages between layers and between high- and low-voltage windings are only the voltage of one layer since successive layers are connected in series progressively.



EFFECTIVE INTER-LAYER COOLING. Schematic diagram of "concentric layer" winding showing six layers insulated by flanged cylinders. Dotted lines show path of oil past each turn of the winding.

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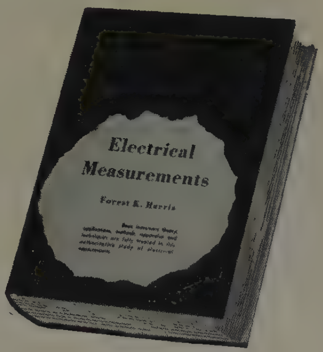

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INDUSTRIAL NOTES ....

National Varnished Products Changes Name. The National Varnished Products Corporation has changed its name to Natvar Corporation. The change was made because the company has been long known in its field by its trade name, "Natvar," and also because the former name no longer adequately covers the full range of products which the Natvar Corporation manufactures.

Secretary of G-E Retires. William W. Trench, Secretary of the General Electric Company for almost 24 years, has retired. Elected Secretary at the age of 36, Mr. Trench has been one of the youngest officers in the company.

General Electric has also announced the expansion of its aviation equipment business to include a new operation for the design, manufacture, and sale of turbine-driven accessories for jet engines and aircraft. J. P. Turner, Jr. has been made head of this new accessory turbine business. Manufacturing and engineering headquarters are located at the River Works plant in Lynn, Mass.

Recent appointments made by the company are: Carl A. Salmonsen, general manager, Industry Control Department, Schenectady, N. Y.; Neil J. Curlee, manager of manufacturing, product service, major appliance division, Louisville, Ky.; L. E. Thompson, manager of marketing, air conditioning division, Bloomfield, N. J.; and John H. Painter, special representative for General Electric broadcast equipment, Washington, D. C.

Sylvania Expands Electronics Division. Sylvania Electric Products, Inc., has announced plans for a new electronics division headquarters plant at Woburn, Mass. When completely equipped, it will represent an investment of four million dollars, and will serve as headquarters for all present Sylvania electronic production facilities in the Boston area. The company has also purchased a building in Newton, Mass., for magnetron and klystron production.

Barber-Colman Purchases Wheelco. The Barber-Colman Company of Rockford, Ill., has purchased the principal assets of the Wheelco Instruments Company, Chicago. Present plans are to continue current operations in Chicago until such time as manufacturing facilities can be transferred gradually to Rockford in a manner that will result in very little interruption in shipments.

Buttner Made President of Federal Telecommunication. Harold H. Buttner, Vice-President of the International Telephone and Telegraph Corporation, has been elected President of Federal Telecommunication Laboratories, Inc., a research unit of International Telephone and Telegraph.

National Research Activates Subsidiary. The National Research Corporation has announced the activation of a wholly-owned subsidiary, Vacuum Metals Corporation, Cambridge, Mass., which will undertake the commercial exploitation of certain of the developments arising from research activities of the parent corporation in the metallurgy field.

Landry Elected Vice-President of Western. George A. Landry, formerly President of the Sandia Corporation, has been elected a Vice-President of the Western Electric Company, Inc.

Nagler Retires From Allis-Chalmers. Forrest Nagler, manager and chief engineer of the Allis-Chalmers Manufacturing Company's atomic power section, has retired. The company has also announced the assignment of James C. Barnett, N. William Morelli, and E. Robert Perry as assistant engineers at the company's Boston works.

Alcoa Appointments. Harold C. Erskine has been named to the post of assistant division manager for the Aluminum Company of America's die casting operations. H. J. Morrison succeeds Mr. Erskine as manager of the company's Cleveland works.

Bloomberg to Supervise Du Mont Sales Activities in Midwest. Herbert Bloomberg, central district sales manager for the television transmitter division, Allen B. Du Mont Laboratories, Inc., has been named to supervise the division's sales activities in 15 midwestern states.

General Cable Appoints Shull. The General Cable Corporation has appointed L. P. Shull as district manager of the lake district with headquarters in Detroit, Mich. Mr. Shull succeeds W. A. Craveson, who is retiring, but will act as special consultant.

Bartlett Named Westinghouse Transformer Division Manager. Chris H. Bartlett has been appointed manager of the transformer division of the Westinghouse Electric Corporation.

Erickson Made Vice-President of Daystrom. Robert Erickson has been made Vice-President of operations of the Daystrom Instrument Division of Daystrom, Inc.

NEW PRODUCTS . .

Sonic Oscillator. A sonic oscillator for experimental work with sound waves has been developed by the Raytheon Manufacturing Company. This magnetostriction oscillator consists of three parts: an electronic driving element, a hollow vibrator column, and a cup assembly.

(Continued on page 22A)

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(*Continued from page 16A*)

Two sizes are available—a small unit operating at 9,000 cycles has a recommended capacity of 25 cubic centimeters and delivers approximately 50 watts to the magnetostriction rod; the larger unit has a capacity of 50 cubic centimeters and delivers 200 watts at a frequency of 10,000 cycles. Units already in use in bacteriological and biological research have demonstrated that bacteria may be disintegrated rapidly to permit the extraction of antigens and other biological substances. Other experiments have resulted in methods of preparing more stable emulsions or have pointed the way to improvements in heavy chemical manufacturing processes. More information on the instrument may be obtained from Department *6470NR*, Raytheon Manufacturing Company, Waltham 54, Mass.

Air-Cooled Transmitting Tube. An air-cooled transmitting tube developed for use in ultrahigh-frequency television has been announced by the General Electric Tube Department. The new tube is designed to operate at up to 900 megacycles with a peak output of 1 kw. A ceramic and metal envelope increases the tube's resistance to high temperatures and shock, and minimizes the problem of high-frequency losses. In class *B* service as a grounded-grid broad-band amplifier, the tube has a power gain factor of 10; maximum ratings at sync level include: d-c plate voltage, 4,000 volts; d-c screen voltage, 600 volts; d-c plate current, 0.7 ampere; plate input, 215 kw; plate dissipation, 1.5 kw. The tube can also be used in narrow-band class *C* service as an amplifier or oscillator or it may be applied to use in high-frequency dielectric heating equipment. Additional information on the tube, the *GL-6183*, may be obtained from the General Electric Company, Tube Department, Schenectady 5, N. Y.

Magnetic Tape Recorder. The Ampex Electric Corporation, Redwood City, Calif., has developed a magnetic tape recorder to meet the standards of high-frequency telemetering and applications in the use of rockets, guided missiles, and computers. The recorder, model *500*, reproduces 100 to 100,000 cycles per second with less than 0.1 per cent peak-to-peak limit. Made to conform to *JAN* specifications, provisions are made to record four individual data tracks. A signal-to-noise ratio is attained that is well over 40 decibels below 1 per cent harmonic distortion when measured in 15 per cent bandwidths. A speed-lock unit included in this equipment eliminates any d-c error by automatically adjusting the speed of the recorder during playback. The tape is rigidly held to a capstan by vacuum, and since both the record and playback heads contact the tape at the capstan, tape scrape and vibration are reduced to a minimum. The capstan is coupled directly to a damped flywheel which is belt-driven by a high-speed hysteresis synchronous motor. Further information is available from the company upon request.

(*Continued on page 34A*)

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(*Continued from page 22A*

High-Gain Preamplifier. The Brush Development Company has made available a high-gain a-c preamplifier, designed to permit the extension of the measurable range of graphic recording instruments or cathode-ray oscilloscope into the microvolt region and maintain a relatively flat frequency response from 0.2 to 400 cycles per second. The instrument, model *BL-954*, was made for use with magnetic direct-writing oscillographs and medium- or low-gain amplifiers to permit immediately available permanent records of measurements of electrical phenomena in the microvolt region such as brain, heart, and nerve potentials or research and industrial laboratory measurements. Voltage gain of the instrument is 200,000 times when operated push-pull, and when used with direct-writing oscillographs and amplifiers is sufficient to give 1 millimeter of pen deflection on the oscillograph chart per 215 microvolts input. A standard cell furnishes voltage for an internal calibration circuit. A detailed description of the preamplifier may be obtained from The Brush Development Company, Instrument Division *23*, 3405 Perkins Avenue, Cleveland 14, Ohio.

Magnetic Brake. A new magnetic brake design that eliminates all levers and linkage found in conventional units has been developed by the Reuland Electric Company, Alhambra, Calif. The brake contains only six major operating parts and features a direct automatic set and release action between the solenoid and armature. This solenoid is of a 1-piece "doughnut" design that permits the motor's output shaft to extend completely through the brake. This feature permits the user to utilize both ends of the motor shaft for powering two pieces of equipment when desired. The brake sets by spring action when the current is off and releases magnetically when current is reapplied. Engineering folder number *MB-1000* which describes the brake more fully may be obtained by writing to the company.

Gammometer. The model *AH-2* gammometer is a radiation measuring instrument developed by the Ohmart Corporation, 2347 Ferguson Road, Cincinnati 38, Ohio. The radioactive-sensitive element in the instrument is a cell in which radioactive energy is converted directly into electric energy. Use of this cell eliminates the need for a high-voltage power supply, and only one vacuum tube is required. Samples may be placed in a well within the cell, minimizing geometry errors and permitting the measurement of much larger quantities of activity than when slides must be prepared. The instrument is direct reading in microcuries. As the well will accomodate samples having volumes up to 200 milliliters, 1 microcurie range can be used to measure concentrations of activity down to 5 by 10^{-10} curies per milliliter. Ranges of the instrument are 1, 10, 100, and 1,000 microcuries full scale. The gammometer is available calibrated in terms of radium (standard),

(*Continued on page 46A*)

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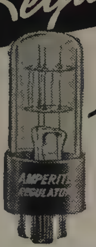

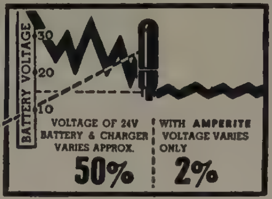

Amperite REGULATORS are the simplest, lightest, cheapest, and most compact method of obtaining current or voltage regulation . . . For currents of .060 to 6 Amps. . . . Hermetically sealed; not affected by altitude, ambient temperature, humidity.
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AMPERITE CO., Inc., 561 Broadway, New York 12, N. Y.
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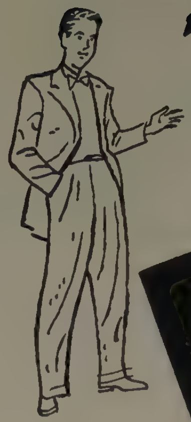

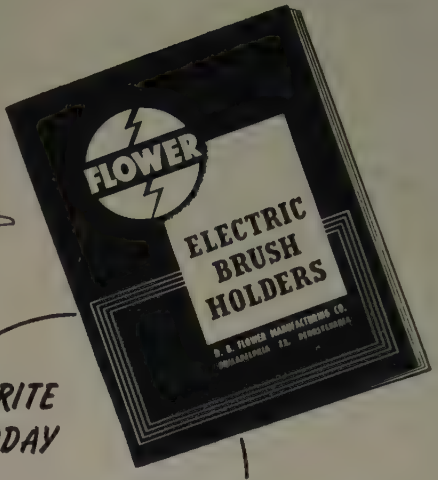

WRITE TODAY

- Discover for yourself why it pays to specify FLOWER Electric Brush Holders! Discover how FLOWER saves maintenance time and money! Get the facts! Ask for Catalog No. 4. Write today!

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D. B. FLOWER MANUFACTURING CO.
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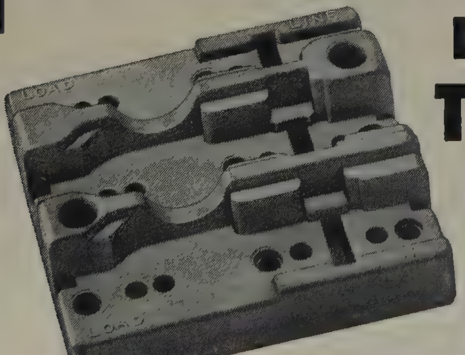
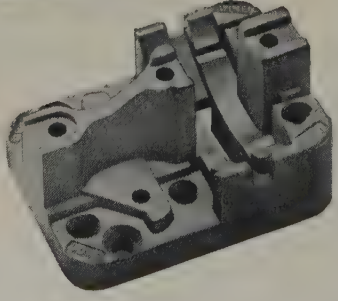
DO YOU HAVE AN INSULATOR DESIGN LIKE THIS ?





Whether your insulator designs are simple or complex, whether they call for special or routine production, Universal can meet your exact requirements. In addition to high dielectric and physical strength, Universal porcelain insulators are unaffected by heat, cold, moisture, fumes and acids.

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1560 EAST FIRST STREET SANDUSKY, OHIO
TRADE MARK

New AIEE Standard for
LOW-VOLTAGE AIR CIRCUIT BREAKERS

Standard and Application Guide number 20, prepared by a Working Group for Low-Voltage Air Circuit Breakers of the AIEE Committee on Switchgear, applies to all air circuit breakers with interrupting rating over 10,000 amperes, as follows:

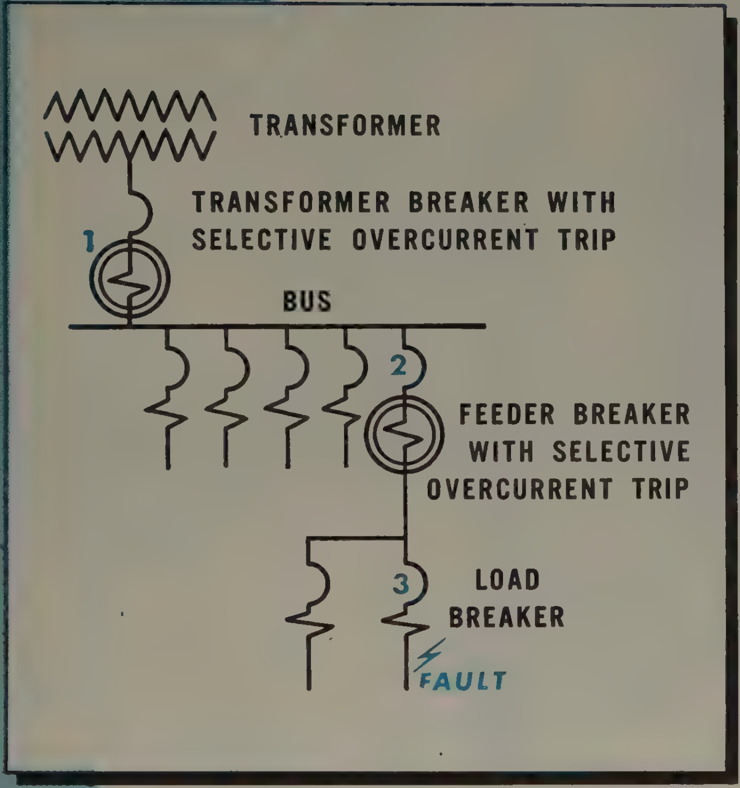
- Air circuit breakers 1,500 volts a-c or less and 3,000 volts d-c or less
- All field discharge breakers comprising air circuit breaker contact elements with field discharge contacts added of any ampere rating single pole or multipole
- Air circuit breakers assembled as integral units in supporting and enclosing housings of insulation material for voltage ratings up to and including 600 volts alternating current, 250 volts direct current
- Air circuit breakers, when in individual enclosures usually built of steel for separate mounting

Copies may be obtained for the price of $0.60 (there is a 50 per cent discount available to AIEE members) from:

Order Department
AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS
33 West 39th Street New York 18, N. Y.

5-52

COSTS LESS THAN YOU THINK


TRANSFORMER
1
TRANSFORMER BREAKER WITH SELECTIVE OVERCURRENT TRIP
BUS
2
FEEDER BREAKER WITH SELECTIVE OVERCURRENT TRIP
3
LOAD BREAKER
FAULT

HOW SELECTIVE TRIPPING WORKS

I-T-E circuit breakers, arranged in series, are *preset* to open in *definite sequence* (3, 2, 1 in diagram). If there is a sudden overcurrent or short circuit in any branch of the system, only the breaker (3) closest to the fault will open. Other breakers—other production machinery—in the system are unaffected.

ANOTHER I-T-E "FIRST"

Here is one more I-T-E "first"—another major I-T-E development to help industry protect production and save. Originally developed for the Navy during the War, the I-T-E Direct-Acting Selective Overcurrent Tripping Device has since been refined and perfected for industrial and utility use.

Call on I-T-E engineers—specialists in circuit breakers and switchgear—to see how positive, dependable I-T-E *Direct-Acting* Selective Tripping can protect your plant operation. See how much you can save.

For selection and application data on I-T-E large air circuit breakers, including selective tripping arrangements write for Catalog Section 1003 today. I-T-E Circuit Breaker Co., 19th and Hamilton Sts., Phila. 30, Pa.

I-T-E

LOW-VOLTAGE SWITCHGEAR

I-T-E CIRCUIT BREAKER CO. • 19TH AND HAMILTON STS. • PHILADELPHIA 30, PA.

CANADIAN MFG. AND SALES: EASTERN POWER DEVICES, LTD., TORONTO • EXPORT SALES: PHILIPS EXPORT CORP., N. Y. 17, N. Y.

A *NEW* BALLANTINE
Sensitive, Wide Band
Electronic Voltmeter

MODEL 314
Price $265

To measure	**1 millivolt to 1000 volts**
from	**15 cycles to 6 megacycles**
with accuracy of	**3% to 3 mc; 5% above**
with input impedance	**6 mmfds shunted by 11 megs**

When used without probe, sensitivity is increased to 100 MICRO-VOLTS but impedance is reduced to 25 mmfds and 1 megohm

Featuring customary Ballantine
SENSITIVITY • ACCURACY • STABILITY

- Same accuracy at *ALL* points on a logarithmic voltage scale and a uniform DB scale.
- Only *ONE* voltage scale to read with decade range switching.
- No "turnover" discrepancy on unsymmetrical waves.
- Easy-to-use probe with self-holding connector tip and unique supporting clamp.
- Low impedance ground return provided by supporting clamp.
- Stabilized by generous use of negative feedback.
- Provides a 60 DB amplifier flat within 1 DB from 50 cycles to 6 mc.

Write for catalog for more information about this and other BALLANTINE voltmeters, amplifiers, and accessories.

BALLANTINE LABORATORIES, INC.
120 Fanny Road, Boonton, New Jersey

(Continued from page 34A)

cobalt-60, or iodine-131. For measurement of ambient field intensity the gammometer is available calibrated in milliroentgen per hour. Full details may be obtained from the Ohmart company upon request.

Short Finder. A new device called the short finder has been announced by the International Products Manufacturing Company which enables anyone to detect and locate short-circuited windings in generator and starter armatures quickly and easily. The device consists of an aluminum base casting to which is securely mounted a special type transformer, vertically and horizontally adjustable bearing standards, and a vertically adjustable trouble indicator. Two heavy test prods with leads are mounted at the back of the base casting and are used for blowing out copper and solder short circuits. To locate and remove short circuits on a generator armature the armature shaft is placed on the bearing standards, the commutator at the right, the armature core centered over the transformer poles. The trouble indicator is then adjusted, and when the foot-switch is pressed, the armature rotates into position by itself and stops, while the trouble indicator points to the closest slot in which one of the two short-circuited coils is to be found. The operator then marks this slot with a piece of chalk, and with the power on, gives the armature a slight spin by hand so that the armature turns itself over, while the trouble indicator points to the closest spot opposite the first indicated slot. Here again the operator marks this slot with chalk. To determine which of the two positions wherein the short circuit is to be found, the armature is gently rocked by hand with the power on. The indicated slot offering the least amount of resistance to this rocking is the slot containing the short-circuited coil. The short circuit finder operates from a normal line voltage of 115 volts alternating current, 50 or 60 cycles, single-phase supply. International Products Manufacturing Company, 1450 South Michigan Avenue, Chicago 5, Ill.

Powerstat Variable Transformer. The Superior Electric Company has introduced a variable transformer rated 120 volts, 60 cycles, single-phase input with an output of 0 to 120/132 volts, 1.25 amperes, 150/160 volt-amperes. It is designed for 50-, 100-, and 150-watt applications. The instrument, named the Powerstat *10*, will supply a continuously adjustable voltage to any load up to its rated capacity. It is designed for single hold mounting; its compactness permits installation under a 3-inch chassis. Further details will be furnished by R. F. Greene, The Superior Electric Company, Bristol, Conn.

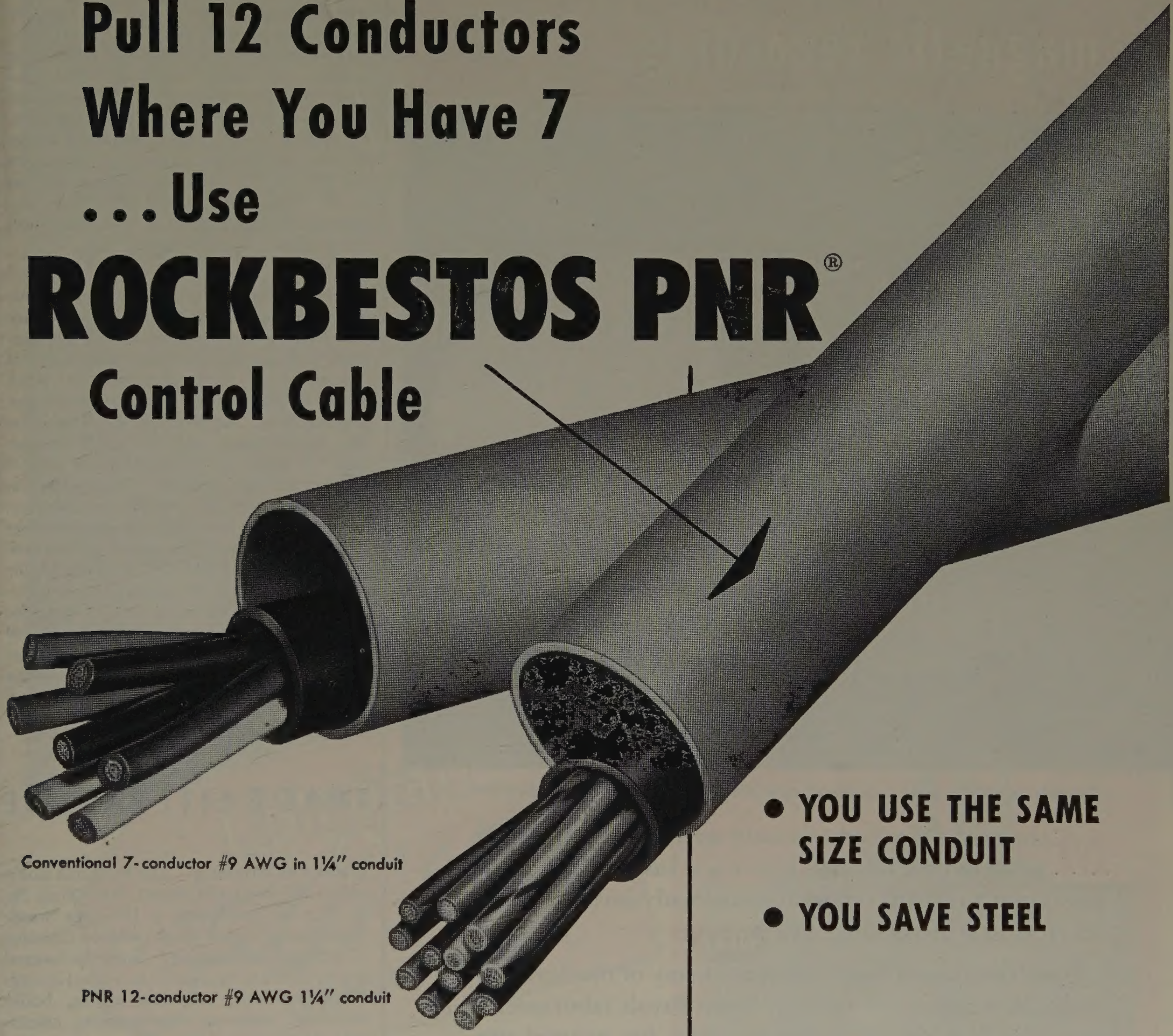
Voltmeter. The Southwestern Industrial Electronics Company, 2831 Post Oak Road, P. O. Box 13058, Houston 19, Tex., has developed a new test instrument, the

(Continued on page 72A)

Pull 12 Conductors Where You Have 7 ...Use

ROCKBESTOS PNR®

Control Cable



Conventional 7-conductor #9 AWG in 1¼″ conduit

PNR 12-conductor #9 AWG 1¼″ conduit

- **YOU USE THE SAME SIZE CONDUIT**
- **YOU SAVE STEEL**

Because Rockbestos PNR Control Cable is 46%* smaller in area than competitive control cables, it enables you to put 12-conductor PNR where you would use 7-conductor cable. This means you save critical steel conduit and fittings, because you put more conductors in a given conduit. Write for the PNR story.

QUICK FACTS ABOUT PNR

- 46% smaller area* . . . 28% smaller diameters*. Use smaller conduit and fittings or put more conductors in present conduit.
- Dielectric breakdown . . . over 40 times operating voltage.
- Lighter and smaller. Easier to handle, store, ship, pull through conduit.
- Flexible to —25°C (—13°F). No cracking!
- Rated 600 volts . . . conductor operating temperature 75°C (168°F).

*Average determined by comparison with competitive control cable.

ROCKBESTOS PNR

... another different, better cable by

ROCKBESTOS PRODUCTS CORPORATION, NEW HAVEN 4, CONN.

the originators of **A.V.C.**®

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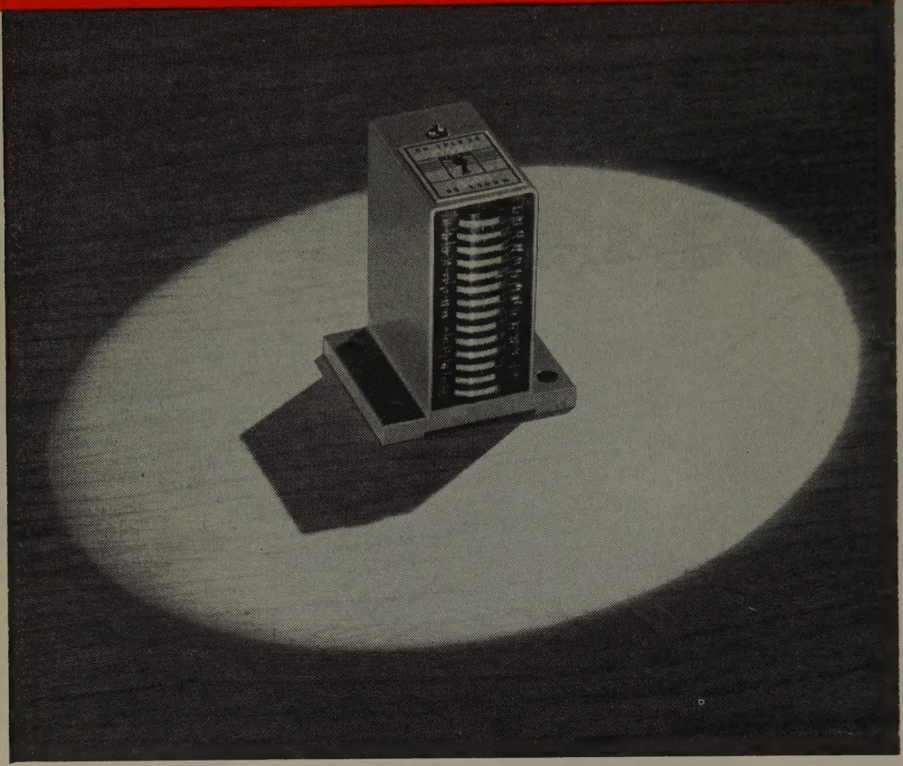
BRUSH and the future of magnetic recording...



Multiple recording head capable of recording 14 channels simultaneously.

MAGNETIC RECORDING is only an infant in the field of electronic devices, but it is a lusty infant. First developed to record sound, it has already invaded many other widely diversified fields.

Brush engineers have pioneered many of the developments in magnetic recording. From Brush laboratories came the first practical tape recorder for general use—the Brush Soundmirror.* Other Brush developments have made possible the application of magnetic recording to memory storage, to instrumentation, to multiple channel recording.

Right now in the Brush laboratories, scientists, and engineers are working on projects that will bring new applications, new techniques, and new devices to the field of magnetic recording. In this field, as in piezoelectrics and ultrasonics, Brush's business is the future.

Write for further information about magnetic recording equipment.
*T. M. Reg.

THE Brush
DEVELOPMENT COMPANY
3405 Perkins Avenue • Cleveland 14, Ohio

Piezoelectric Crystals & Ceramics
Magnetic Recording Equipment
Acoustic Devices
Ultrasonics
Industrial & Research Instruments

(Continued from page 46A)

model *R* voltmeter, designed for measurement of d-c potentials, providing direct voltage ranges from 1 volt full scale to 1,000 volts full scale. The instrument also will measure d-c millivolts, alternating voltage and millivolts, and ohms and megohms, and includes a d-c amplifier which will drive a 1-milliampere recorder, has a gain of 200, and a frequency range of zero to 100 kc. Power requirements are 105 to 120 volts alternating current at 60 cycles per second and 80 watts. Additional information is available from the company upon request.

Power Triode. A new power triode intended for ultrahigh-frequency service in television and continuous-wave applications with a maximum plate dissipation of 250 watts has been announced by RCA Victor division of the Radio Corporation of America, Camden, N. J. The tube can be operated with full plate voltage and full input at frequencies up to 900 megacycles per second. Compensation reduction in ratings permits operation at frequencies up to 2,000 megacycles per second. A forced-air-cooled grounded-grid tube, the *RCA-6161*, is designed for use particularly with coaxial-cylinder circuits. The design of the tube provides low-inductance large-area radio-frequency electrode terminals for insertion in cylinders, and permits effective isolation of the plate from the cathode. The company will furnish further details.

TRADE LITERATURE

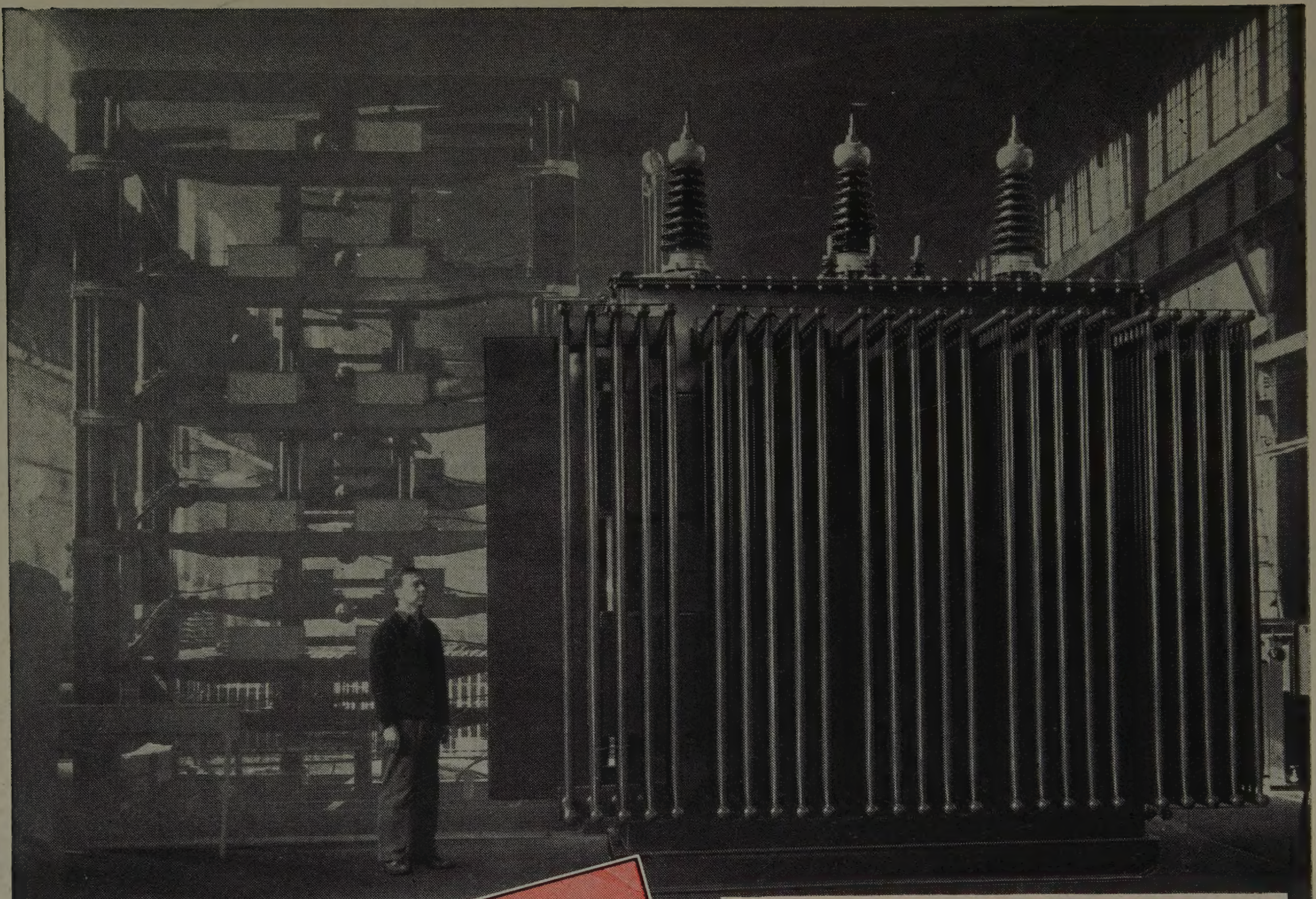
Water Conditioning. The Permutit Company, 330 West 42d Street, New York 36, N. Y., has published a 116-page water conditioning data book which contains 77 tables of information. Subjects covered are hydraulics, impurities in water, chemical conversions, saturated steam, boiler feedwater make-up requirements, chemicals, alkalinity relationships, and specific gravities. This leatherette-bound volume is available upon request to practicing engineers and those who work with water conditioning problems.

The Permutit Company also has announced as available a 32-page booklet, "Permutit Hot Process Water Softeners."

Variable-Area Meters. A 40-page handbook presents complete data for the specification, use, and modification of variable-area flow meters. The handbook may be obtained by writing to the Fischer and Porter Company, Hatboro, Pa.

Welding Steel Castings. "Recommended Practice for the Welding of Steel Castings" is a 40-page booklet published by the Steel Founders' Society of America. Complimentary copies are available to engineers and technicians who request it on their business letterhead from the Tempil Corporation, 11 West 25th Street, New York 11, N. Y.

(Continued on page 74A)



Uptegraff POWER TRANSFORMERS

Individually **DESIGNED, BUILT, TESTED**

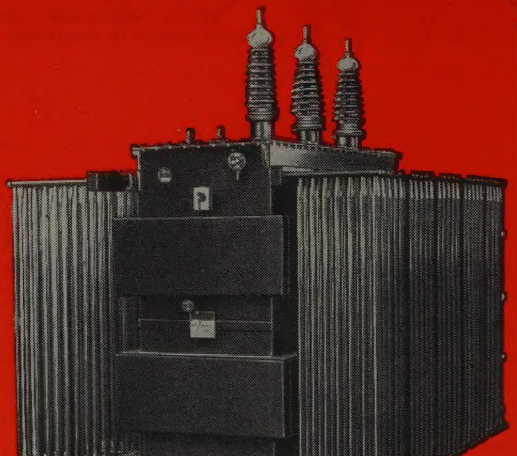
Every Uptegraff Power Transformer is made to exacting standards for quality performance and is thoroughly tested as an individual unit before shipment.

Sensible design and careful construction are combined to insure long life and dependability. Consider these features:

1. Core and coils thoroughly dried and oil impregnated while warm.
2. Super-sensitive electronic leak detection eliminates the smallest leaks in tanks and bushings.
3. All external tank surfaces shot blasted and covered with three coats of enduring paint; bottom of tank is under-coated.

These are just a few of the many details that make dependability.

We can quickly meet your needs with transformers built to your specifications.



6,000 KVA, 67 KV Uptegraff Power Transformer. Photograph at top of page shows the same unit on the Uptegraff test floor. Note the high-strength radiator design, with tubes spaced for easy cleaning and maintenance. This is an inert-gas, oil seal transformer.

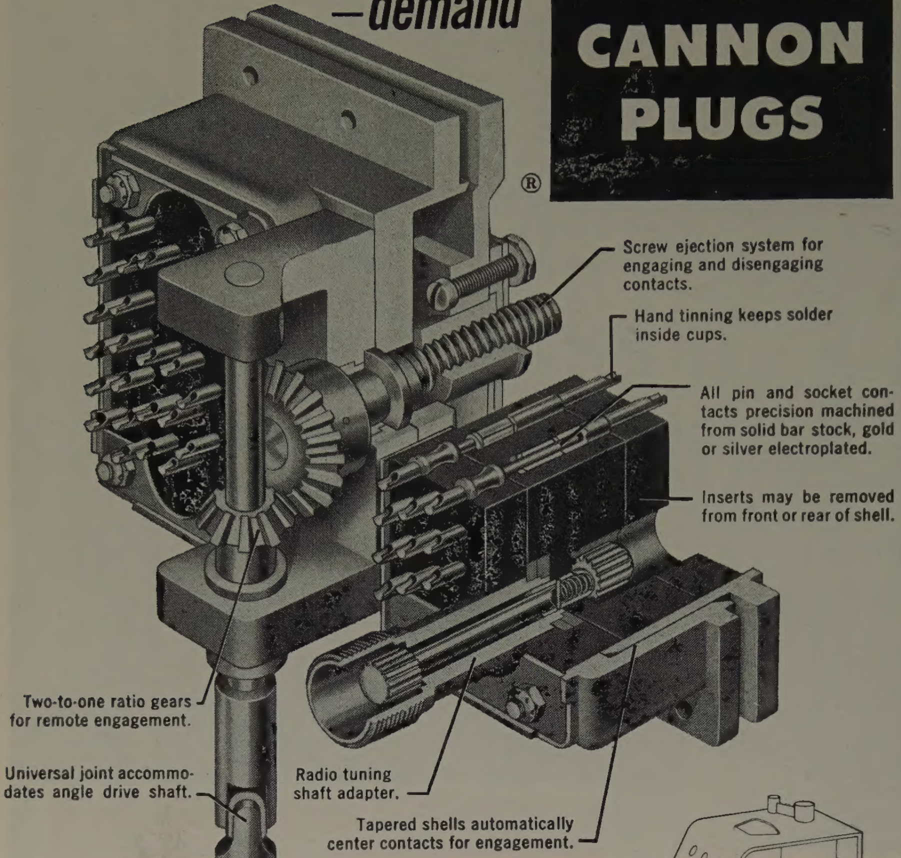
R. E. UPTEGRAFF MANUFACTURING CO.

SCOTTDALE, PENNSYLVANIA

Makers of: *POWER • DISTRIBUTION • INSTRUMENT SPECIALTY TRANSFORMERS*

Here's why those in the know — demand

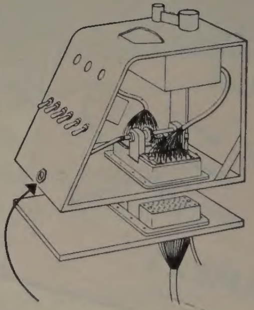
CANNON PLUGS ®


Screw ejection system for engaging and disengaging contacts.
Hand tinning keeps solder inside cups.
All pin and socket contacts precision machined from solid bar stock, gold or silver electroplated.
Inserts may be removed from front or rear of shell.
Two-to-one ratio gears for remote engagement.
Universal joint accommodates angle drive shaft.
Radio tuning shaft adapter.
Tapered shells automatically center contacts for engagement.

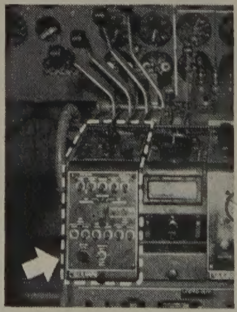
This highly specialized DPD2 Cannon Plug, a member of the DP Series, has its principal use in aircraft instrument panels and remote radio control equipment. But, like many other Cannon Plugs, it has found its way into other fields where the highest quality is needed and where the value of long, trouble-free performance is recognized.

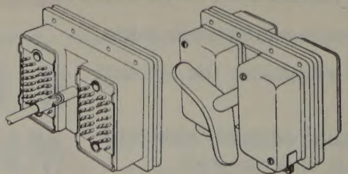
Originally this 2-gang connector was designed to assist in the standardization of radio and instrument assemblies so that such equipment might be interchanged between similar aircraft. It allows for compact design in close quarters with access from the front only. This type of application and variations of the fittings are shown at right. Any Cannon DPD insert may be placed within the shell, with or without tuning shaft, coax, twinax, large or small contacts, provided the separation forces of both halves are similar.

This plug typifies the close attention to important detail that distinguishes every Cannon Plug—the world's most extensive line. If you are looking for real value, regardless of the field you work in, your best bet is Cannon.



Connector is separated by turning slotted shaft here. Complete unit may then be removed from pedestal, shown below.





(Left) Same Cannon Plug without tuning shaft. Straight drive instead of 90° gear. (Right) Similar DPD2 with Dzus wing nut extraction method and junction shells. There are several other variations. Write for details.

CANNON ELECTRIC

Since 1915

CANNON ELECTRIC COMPANY
LOS ANGELES 31, CALIFORNIA

Factories in Los Angeles, Toronto, New Haven. Representatives in principal cities. Address inquiries to Cannon Electric Company, Dept. E-117, P. O. Box 75, Lincoln Heights Station, Los Angeles 31, California.

(*Continued from page 72A*)

Switchgear. Unitized low-voltage metal-enclosed switchgear is described in a 30-page booklet available from the Westinghouse Electric Corporation, Box 2099, Pittsburgh 30, Pa. Request *B-5282*.

Miniature Lamps. A new 36-page "Miniature Lamp Catalogue" listing and illustrating hundreds of types and their applications, is offered by the General Electric Company, Lamp Division, Nela Park, Cleveland, Ohio.

Electric Brush Holders. The D. B. Flower Manufacturing Company, 1217 Spring Garden Street, Philadelphia 23, Pa., has made available upon request a 50-page catalogue describing their electric brush holders.

Radiation Counter Tubes. Amperex Electronic Corporation has published a booklet on their permanent sensitivity radiation counter tubes. It may be obtained by writing to the company at 25 Washington Street, Brooklyn 1, N. Y.

Constant Voltage Transformers. The Sola Electric Company, 3633 West 16th Street, Chicago 50, Ill., has issued a new booklet, number *P-28-CV-142*, which describes Sola constant voltage transformers. The bulletin may be obtained upon request.

Galvanometers. The complete line of standard galvanometers, dynamometers, d-c indicating amplifiers, and accessories for use in null-balance or calibrated deflection measurements is presented in a new catalogue section *ED*, available from the Leeds and Northrup Company, 4934 Stenton Avenue, Philadelphia 44, Pa.

Motors. The Westinghouse Electric Corporation, Box 2099, Pittsburgh 30, Pa., has published two new booklets: number *B-4731* contains design and application features of life-line motors (now made in ratings up to 700 horsepower); bulletin *B-4792* describes Westinghouse motors and controls in the chemical processing industries. Copies of both booklets may be obtained from Westinghouse.

Selenium Rectifier Stacks. Booklet *GET-2350* issued by the General Electric Company describes the basic characteristics and applications of selenium rectifier stacks. Copies are available from the Lighting and Rectifier Department of the General Electric Company at Schenectady 5, N. Y.

Regulators. Functions and applications of Regohm finger-type voltage and current regulators are analyzed in engineering bulletin *505.00* issued by the Electric Regulator Corporation, 50 Day Street, South Norwalk, Conn. It may be obtained upon request.

Compression Joints. The Thomas and Betts Company, Inc., 76A Butler Street, Elizabeth, N. J., offers a new catalogue on their compression joints for copper and aluminum cable. Copies of catalogue *67*, should be requested on business letterhead.